Annual Subscription Price, $4. 109 *Published Ten Times a Year.*

ASTRONOMY and ASTRO-PHYSICS.

NOVEMBER, 1892.

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Entered at the Post Office at Northfield, Minn., for transmission through the mail at second class rates.

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Astronomy and Astro-Physics.

NEW SERIES No. 9. NOVEMBER, 1892. WHOLE No. 109

General Astronomy.

THE PROBABLE ORIGIN OF METEORITES.*

GEORGE W. COAKLEY.†

In the problem discussed in this paper the term *meteorites* is used to denote only those solid masses of metals or minerals which have been ascertained to have fallen upon the Earth from some source beyond it. The term is used particularly to exclude the case of a *shooting-star*, or a shower of such stars, as the thirty-three year November shower, or the annual August shower, or any similar meteoric display.

In the popular mind, and even in the minds of many astronomers, no sufficient distinction is made between the nature, or the flight, of a solid meteoric mass, and that of a shooting-star or meteoric shower. The great November shower of meteors has been identified with the motion and path of a comet; so also has the annual August shower been identified with the motion and orbit of another comet. Other similar identifications have been made; and the conclusion has been securely reached that these meteoric displays are the consequence of the Earth's passing through the intersections of her orbit with those of some great comets, and that the fragments, into which these comets have been divided by some cause, traverse our atmosphere with immense velocities. So great is the velocity with which these numerous small pieces of a comet rush through our atmosphere, that they are instantly inflamed, giving us the magnificent display of a meteoric shower, or sometimes of a single shooting-star. Every astronomer who examines the evidence for this view of the meteoric showers must admit its truth. But some go farther and include the case of *meteorites*, or solid bodies falling upon the Earth, in the same cometary theory.

There are, however, several important facts which seem to separate entirely the case of these solid meteorites from that of

* Communicated by the author.

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the shooting-star, or the meteoric shower. For, while the shooting-star, or one of those that constitute the shower, is never seen for more than half a second of time, or a second at most (except that it may leave an illuminated trail after it, of more permanent duration), the meteorite, on the contrary, when seen in its flight through the air, is visible sometimes for a minute or more. This is undoubtedly owing to its much slower velocity than that of the single or multiple shooting-star.

The late Professor J. Lawrence Smith, of Kentucky, was for many years one of the most persistent and painstaking students of all ascertainable facts with regard to meteorites, or meteoric stones. He collected the evidence of their phenomena, traced the appearances they presented to observers, and their whole history, and he procured and analyzed many specimens of them. Among his latest conclusions with regard to meteorites were, first, that they had, from all accounts, a much slower motion than that of the shooting-star, or *meteor proper*; and secondly, he announced the conclusion that they probably had a totally different origin from that of the shooting-stars, or meteoric showers. He also noticed their close resemblance, in chemical composition, to volcanic minerals.

Professor Ball, the Astronomer Royal of Ireland, in his interesting work, "The Story of the Heavens," says:

"We have shown that the well-known star-showers are all intimately connected with comets. In fact each star-shower revolves in the path pursued by a comet, and the shooting-star particles have, in all probability, been derived from the comet. Showers of shooting-stars and comets have, therefore, an intimate connection; but there is no ground for supposing that meteorites have any connection with comets,—the facts, indeed, all seem to me to point in the opposite direction."

"Meteorites have never been known to fall from the great star-showers. No particle of a meteorite was ever dropped from the *countless host* of the Leonids, or of the Perseids; the Lyraids never dropped a meteorite, nor did the Geminids, or the many other showers with which every astronomer is familiar. There is no reason to connect meteorites with these showers, and there is, accordingly, no reason to connect mèteorites with comets. Indeed, the appearance of a comet, and the history of its movements and its changes, seem entirely at variance with the supposition that it is composed of materials resembling those in meteorites."

Professor Ball regards comets, as he elsewhere argues, as entirely of a gaseous nature, with nothing *solid* about them. He also points out the slow motion of meteorites, and argues that if they passed through our atmosphere with anything like the velocity which the shooting-star meteors are known to have (some twenty-six miles per second, as Professor Young states), the meteorites would be almost instantly vaporized and burned up, so that nothing but their constituent gases and ashes would reach the Earth. Still the motion is rapid enough to heat the meteorites so much as to form a fused crust around them to a small depth, and also to cause them frequently to explode into fragments with loud detonations, which have been heard to accompany their flight.

With regard to the nature and origin of meteorites, Professor Ball states the following "theory entertained by the Austrian mineralogist (Tschermak). He has made a study of the meteorites in the rich collection at Vienna, and he has come to the conclusion that the meteorites have had a volcanic source on some celestial body." Professor Ball then says, "Let us attempt to pursue this hypothesis and discuss the problem which may be thus stated: Assuming that meteorites have been ejected from volcanoes, on what body or bodies in the universe must these volcanoes be situated? This is really a question for astronomers and mathematicians. Once the mineralogist assures us that these bodies are volcanic, the question becomes one of calculation and of the balance of probabilities."

After trying the various planets of our solar system, including the asteroids and our Moon, he finds it difficult to place the volcanoes on any of them, with power to send us the meteorites. He therefore returns to the Earth, placing here the required volcanoes, but acknowledging frankly that none of our *present* volcanoes have the power to eject the meteorites with force enough to cause them to wander through the planetary regions, and to subsequently return to us, after many revolutions around the Sun. He thinks that in the old geologic times, some millions of years ago perhaps, the power of our volcanoes must have been sufficient to throw out these materials, and that they are now finding their way back to their old home.

The objections to Professor Ball's location of the volcanoes that send forth the projectiles to become meteorites, are, first, the enormous force required to perform this work. It is known that the velocity acquired by a body falling upon the Earth from an *infinite distance* is nearly seven miles per second, and that a force would be required that should impart this same velocity of seven miles per second to a projectile, to cause it to escape the Earth's power of attracting it back to its surface. The maximum velocity imparted to a cannon ball may be taken to be 2,000 feet per second. But the force to impart seven miles per second would be more than eighteen times as great as that required for the cannon ball. Could the Earth's volcanoes at any time have supplied so great a force? The required force would be even many times greater than that above stated; because the resistance of the Earth's atmosphere would, in addition, have to be overcome. This resistance tends to rapidly reduce the initial velocity imparted to the projectile, so that sufficient additional velocity beyond the seven miles per second must be supplied to overcome the resistance.

Secondly, if the required velocity were supplied from the Earth, the projectiles would become small planets revolving around the *Sun*, not around the Earth, since they would have to fly far beyond the moon, in order to be beyond the Earth's power of bringing them back to her surface in a short time; and besides they would retain the Earth's velocity of 18 miles per second in her annual orbit. The theory proposed in this paper, to account for the meteorites, is not the writer's own; it is not new. It prevailed during most of the last century, and was maintained by the greatest astronomers and mathematicians. It is simply that the volcanoes claimed as the origin of meteorites by the Austrian mineralogist, and laboriously sought after by Professor Ball, existed formerly in an active state on our Moon, and that they, and they alone, had the requisite power to throw these solid bodies beyond the reach of the Moon's prevailing attraction, and within the controlling attraction of the Earth.

About a century ago the problem of the origin of meteorites, or aerolites, was discussed by Laplace, Lagrange, Poisson, Legendre and other great mathematicians. They generally agreed that the most probable origin was the *formerly active* volcanoes of our moon.

This is what Laplace says in the fifth chapter of the second volume of his "Systeme du Monde," from which the writer translates freely (Sixth Paris edition):

"The attraction of gravity on the surface of the Moon being much less than on the surface of the Earth, and this satellite having no atmosphere which might oppose a sensible resistance to the motion of projectiles, we may conceive that a body thrown with a great force by the explosion of a lunar volcano, might reach, and pass beyond the *limit* where the Earth's attraction would begin to be superior to the Moon's attraction. It would suffice for this purpose, that the body's initial velocity in a vertical direction should be 2,500 meters per second," (about one and a half miles per second.) "Then instead of falling back upon the Moon, it would become a satellite of the Earth, and would describe around the Earth a more or less elongated orbit. The primitive impulse given to the body might be so directed that it would go straight to meet the Earth's atmosphere; or it might also be so directed that the body would not meet our atmosphere until after many, or even a *very great number of revolutions*. Because it is evident that the Sun's attraction, which changes in a very sensible manner the distances of the Moon and the Earth, ought to produce in the radius-vector of a satellite, moving in so very eccentric an orbit as that of the projected body, *variations* very much larger than those produced in the Moon's radius-vector. The disturbing action of the Sun might at length diminish the perigee distance of this new satellite to such a degree that the body could penetrate within our atmosphere. This body, in traversing the atmosphere with a great velocity would experience therefrom a very great resistance, and would at last be precipitated upon the Earth. The friction of the air against its surface would suffice to inflame it, and to cause it to detonate, if it contained materials suitable for these effects. It would then afford us all the phenomena which aerolites present.

If it were well proved that these bodies are not the products of our own volcanoes, nor of our atmosphere, and that it is necessary to seek their cause outside, in the celestial spaces, then the preceding hypothesis, which also explains the identity of composition observed in aerolites, by the identity of their origin, would not be destitute of probability."

This is Laplace's statement of the theory of meteorites, with the *lunar volcanoes* as their origin. It deserves careful comparison with Professor Ball's statement of their lunar origin, and with his reasons for rejecting that origin. They are principally two; first that there are now no active volcanoes on the Moon to send us meteorites at present. This argument applies as well to his theory of their terrestrial origin; for he admits that none of our present volcanoes could supply the requisite force. Secondly he can not admit that the Sun's disturbing force could bring the meteorites within our atmosphere, as Laplace shows it could. This argument also militates against his terrestrial origin of the meteorites, which would require perhaps an even greater perturbation to produce the required effect, since they would revolve around the Sun, and not around the Earth.

After the demonstrations of the great mathematicians no one thought of denying this lunar origin of aerolites, until it was found that the shooting-stars possessed a velocity of more than twenty miles per second. Then it was seen at once that the earth's attraction could never impart to *them* any similar velocity, since the greatest velocity that could be so imparted is a little less than seven miles per second. It follows at once that the shooting-star could not be projected from the moon, and be drawn to the Earth by the latter's attraction. For, in that case, the shooting-star's velocity could not exceed seven miles per second, instead of being more than twenty miles per second.

But the mistake was made of confounding the slowly moving aerolite, or meteorite, with the swiftly moving shooting-star, and thence concluding also that the meteorite could not come from the Moon. The conclusion was a *nonsequitur*, because the velocity really belonging to one class of these bodies, was wrongly attributed to the other very distinct class of the meteorites. It will be observed that Laplace speaks of the *limit of distance* from the Moon, at which the Earth's attraction *begins* to preponderate over that of the moon. Now it is a comparatively easy problem to determine how far from the Moon's center, in every direction, this *limit of distance* extends, and also to determine the *shape* of this limit. The condition for determining it is, evidently, that a body simply placed, without motion, any where on this limit, for any given position of the Earth and Moon, should be *equally attracted* towards the Earth and towards the Moon.

There is in the Astor Library, in New York, a small treatise by the great mathematician, Poisson, on the lunar origin of aerolites, or meteorites, in which he determines this *limit* to be the *surface of a sphere* surrounding the Moon on all sides. But the Moon's centre is not at the centre of this spherical limit. The centre of the sphere is on the prolongation of the line joining the centres of the Earth and Moon, beyond the Moon's surface by nearly her whole diameter.

If we denote by a, the mean distance betwen the centers of the Earth and Moon, where $a = 238,840$ miles, according to Professor Young, then the centre of Poisson's limiting sphere lies beyond the Moon's centre at the distance $\frac{a}{80} = 2,985.5$ miles provided the Moon's mass is $\frac{1}{81}$ of the Earth's mass. The radius of the sphere is $\frac{9a}{80} = 26,769.5$ miles; the distance of the sphere's point, nearest to both the Earth and Moon, is, on the line joining their centres, $\frac{a}{10} = 23{,}884$ miles from the Moon's centre; and the distance from the Moon's centre to the point farthest from both the Earth and Moon, on the prolongation of the line of centres, is $\frac{a}{8} = 29{,}855$ miles.

Any point *within* this sphere is more attracted by the Moon than by the Earth; every point *outside* this sphere is more attracted by the Earth than by the Moon. Only on its surface are the attractions of the two bodies equal.

The advantage of knowing this limiting sphere of equal attraction between the Earth and Moon is, that we are not obliged to determine the velocity with which the Moon must project a body in order to send it to an *infinite distance*; but only the smaller velocity with which the body must be projected to reach the surface of this sphere, or just to pass beyond it, so that the body will not return to the Moon.

The velocity with which a lunar volcano, nearest the Earth, must project a body, to just reach the nearest point of the sphere of equal attraction, at the distance from the Moon's centre equal to 23,884 miles, is found to be 1.443 miles per second. The velocity with which the body must be projected from a lunar volcano farthest from the Earth, on the opposite hemisphere of the Moon, to a distance from her centre equal to 29,855 miles, is found to be 1.450 miles per second. But while the projectile in the former case, thrown *towards* the Earth, is leaving the Moon's surface, and drawn back by her attraction, its flight is being *helped* by the Earth's attraction, which *alone* would impart to it a *final velocity* at the surface of the sphere, equal to 0.292 miles per second.

Hence the lunar volcano nearest the Earth needs only to impart the velocity $1.443 - 0.292 = 1.151$ miles per second in order to cause the projectile to reach the surface of equal attraction. This is only about three times the maximum velocity of 2,000 feet per second, of a cannon ball. In the opposite direction, however, when the projectile is launched from a volcano on the Moon's farthest hemisphere, if there be any there, with the velocity 1.450 miles per second, the Earth's attraction *helps the Moon* to bring it back with a total imparted velocity of 0.292 miles per second. Hence the volcano ought to impart a velocity of $1.450 + 0.292 = 1.742$ miles per second, in order that the body may just reach the sphere of equal attraction. This velocity is only about four and a half times the cannon ball's maximum velocity of 2,000 feet per second. However, it is not improbable that, in this last case, the Earth's attraction would help the Moon to bring back the projectile to her surface. Though it is probable that the Moon's farthest hemisphere has been subject to volcanic action, like the hemisphere nearest to us, yet we know nothing certain with regard to that distant hemisphere. We shall not count on it in any way in the theory of meteorites except that it is now certain that an initial velocity of from three to about four and a half times the maximum velocity of a cannon ball applied in a vertical direction to a projectile at any point of the Moon's surface would bring it to the surface of the sphere of equal attraction between the Earth and Moon.

Indeed we may leave out of account any lunar volcano situated more than 84° on a great circle across the Moon's disk from the point nearest the Earth. In this case every projectile from any volcano within these 84° will be more or less *assisted*, in its flight from the Moon's surface, by the Earth's attraction. The extreme velocity which the volcano alone must supply to the projectile will then be just about four times the cannon ball's maximum velocity; and the least velocity required from the volcano will be three times this maximum velocity of the cannon ball. Hence we have the fact that over a wide range of 168° on a great circle of the Moon's nearest hemisphere, in every direction from its visible centre, a lunar volcano needs only to impart these moderate velocities, of three or four times that of a cannon ball, to send a projectile to the surface of *the sphere of equal attraction* between the Earth and Moon.

Every astronomer knows that the Moon's nearest hemisphere is almost covered, in all directions, by the craters of extinct volcanoes, many of them far greater in extent than any on the Earth. It can hardly be doubted that the Earth's volcanoes are capable of imparting, in a vertical direction, a velocity three, four or five times that of the cannon ball's maximum. Hence these *larger lunar volcanoes* must be considered capable of exerting at least an equal force. The bodies projected from them would reach the surface of the sphere of equal attraction with various velocities, and from all directions within 84° of the Moon's visible centre, on a great circle across her disk. If the greater part of these projectiles had fallen back to the Moon the interior floor of her volcanic craters would present a very different appearance from that observed. They would be filled up with these irregular fragments, instead of presenting usually a deeply excavated and smooth surface, only broken occasionally by a few small volcanic cones, the effects probably of subsequent minor eruptions.

The Moon's volcanoes must have been active for many ages, though they have now been extinct perhaps for millions of years. The explosions, which may have sent forth the masses that have fallen on the Earth, should be considered as having taken place at various periods, after long intervals from the same volcano, and also at different times, and in various directions, from other volcanoes with a different situation on the Moon's surface. The projectiles should not be considered as all starting at once from all the volcanoes; but their ejections should be regarded as spread over long intervals of time, whether from the same or from different lunar volcanoes.

Let us consider more particularly the probable course of some one projectile, thrown from the visible centre of the moon's disk directly towards the Earth, and with just sufficient velocity to cause it to reach the nearest surface of the sphere of equal attraction. What would happen when the projectile reached this point? It certainly would not go back to the Moon, because the Earth's equal attraction would prevent such a result. Neither would it go directly to the Earth, because of the Moon's equal attraction. But the Moon has the same average velocity of about 18 miles per second around the Sun, which the Earth has in her annual orbit. Hence the projectile in consideration, having this same velocity of 18 miles per second, will go around the Sun in an annual orbit just as the Earth and the Moon do. Also the moon has a velocity of about 0.636 miles per second in her relative orbit about the Earth; and the projectile will also have this same velocity eastward, and will therefore revolve about the Earth just as the moon does, and nearly in the same time, and in the same plane. It will become a satellite of both the Sun and the Earth. The perturbations of its orbit about the Earth, by both the Sun and the moon, will be very great; but they may never cause it to fall on the Earth, as even Laplace supposes, because its orbit will be too nearly circular, or of *small eccentricity*. At any rate, if this projectile ever reached the Earth, it would have to be after a very prolonged period. In saying that such a projectile might come straight to the Earth, Lalace must have overlooked its orbital velocity about the Earth, derived from the Moon.

Suppose that another projectile from the visible centre of the Moon's disk were thrown with a slight excess of velocity above that requisite to bring it to the surface of equal attraction.

Then it would become a satellite of the Earth, as well as of the Sun, with an eccentricity of its orbit depending upon the amount of this excess of initial velocity. The apogee of its orbit about the Earth would be near the Moon, or rather near the *surface of equal attraction*, on the side towards the Earth; and its perigee would be diametrically opposite, on the other side of the Earth. As Laplace points out, the Sun's attraction would disturb the figure and dimensions of the projectile's orbit about the Earth, and might bring its perigee nearer the Earth by an amount depending upon the eccentricity of the orbit.

Another projectile from the same volcano, at a different time, might have a greater initial velocity, producing a still greater eccentricity of its orbit about the Earth, with a consequent yet greater disturbance of its perigee. In this way there might be very many projectiles from this one volcano, their ejections being spread over long periods of time, with all sorts of initial velocities within the requisite limits, producing orbits about the Earth with almost every degree of eccentricity, and consequent perturbations by the Sun. Suppose farther that similar projectiles have been thrown, at various times, while the lunar volcanoes were still active, by each of them, wherever placed on the nearest hemisphere of the Moon, and with every degree of initial velocity within the proper limits. The various *directions* as well as the *velocities* of these projectiles would ensure a great variety of eccentricities in their orbits about the Earth. They may continue to revolve around the Earth for many ages, even after the lunar volcanoes became extinct, before the Sun's attraction could bring their perigees so near the Earth as to cause them to penetrate our atmosphere. From the great number and variety of these orbits, the epochs, when their perigees should be so reduced by the Sun's action, might readily be *spread throughout the ages*. Portions of these projectiles may have been dropping upon the Earth for many ages past, and they may continue to do so, for many ages to come.

This theory of the Lunar Origin of Meteorites seems to be far more probable, than their derivations from comets, or from the meteoric ring-systems which have been identified with comets.

The equivalent of Poisson's proof of the *sphere of equal attraction* between the Earth and moon is as follows:

Let C_1 be the moon's centre, and C_2 be that of the Earth; and let their mean distance, $C_1C_2 = a$, the mass of the Earth being denoted by M, that of the moon by m. Then if P be the position of a body equally attracted by the Earth and the moon, a plane may be passed through P, and the line $C_1 C_2 = a$, joining the centres of the two bodies. Let the line of centres be taken as an axis of abscissas, the origin being at the Moon's centre, and the abscissas counted positive towards the Earth. A perpendicular from P to this axis will be the ordinate, and the distance from its foot to the moon's centre, the abscissa of the point P. Let $D_1 =$ the distance of the moon's centre from P, and $D_2 =$ the distance from the same point P to the Earth's centre. Then, evidently, $D_1^2 = y^2 + x^2$, $D_2^2 = y^2 + (a - x)^2$; hence

$$\frac{D_2^2}{D_1^2} = \frac{y^2 + (a - x)^2}{y^2 + x^2}, \qquad (1).$$

But the attraction of the Earth for a body at P is, disregarding its sign, $\frac{M}{D_2^2}$; and the attraction of the moon for the same body is $\frac{m}{D_1^2}$. By supposition these attractions are equal. Hence

$$\frac{m}{D_1^2} = \frac{M}{D_2^2}; \text{ or } \frac{D_2^2}{D_1^2} = \frac{M}{m} = 81, \qquad (2).$$

Comparing (1) and (2) gives

$$\frac{y^2 + x^2 - 2ax + a^2}{y^2 + x^2} = 81, \qquad (3).$$

$$\text{Hence,} \quad y^2 + x^2 + \frac{2a}{80}x - \frac{a^2}{80} = 0, \qquad (4).$$

Equation (4) is evidently that of a circle, whose radius is $\frac{9a}{80}$, and its centre on the prolongation of the line joining the centres of the Earth and moon, at the distance from the latter's centre equal to $\frac{a}{80}$. By making the ordinate $y = 0$, the intersections of the circumference with the line of centres will be found to be $\frac{a}{10}$ from the Moon's centre towards the Earth, and $\frac{a}{8}$ in the opposite direction. Since the point P, may be in every possible plane around the line of centres, and in every such plane we have the same circle, hence this point will be on the surface of a sphere, of which each circle is a section by the plane containing P.

THE MOTION OF THE SOLAR SYSTEM.*

J. G. PORTER.

A new determination of the apex of the solar way, based on the Catalogue of Proper Motion Stars in Publication No. 12 of the Cincinnati Observatory, has just been completed. With the exception of the fundamental stars, the proper motions given in this Catalogue were all re-computed, and in the great majority of cases the available data were considerably improved by re-observation of the stars. The results may therefore be considered as on the whole the most reliable that have yet been published. Notwithstanding the exhaustive investigation recently made by Dr. Stumpe, (see *Astronomische Nachrichten* 2999-3000) it seemed worth while to repeat the computation for the Sun's motion, especially as the stars in the present list are more equably distributed than has generally been the case. The method employed was that given by Schönfeld in *Vierteljahrschrift der Astronomischen Gesellschaft*, XVII, p. 256, the equations of condition containing a term which depends on the supposed rotation of the stars in the plane of the Milky Way. This term, however, as in all previous investigations, appears to be insensible.

The stars were divided into four groups according to the amount of proper motion, and the resulting co-ordidates of the apex of the Sun's way as given by the different groups are as follows:

Proper Motion	No. of stars	R.A.	Decl.	$\frac{c}{\rho}$
″ ″		°	°	″
.15 to .30	576	281.9	+ 53.7	0.16
.30 to .60	533	280.7	+ 40.1	0.30
.60 to 1 20	142	285.2	+ 34.0	0.55
1.20 and over	70	277.0	+ 34.9	1.69

The last column gives the angular motion of the Sun as seen from the mean distance of the stars of each group respectively. Dr. Stumpe has already pointed out that the results plainly indicate that the amount of proper motion affords a more correct criterion of the distance of the stars than does their magnitude.

The most noticeable point in connection with the present investigation is the high declination given for the apex by the first group. I believe it is the most northerly declination which has ever been obtained; and yet the large number of stars and their wide distribution would seem to entitle the result to considerable

* Communicated by the author.

weight. The rather large difference in the direction of the Sun's motion as given by the first group and by the last two can be most readily explained by the supposition of a common drift for the nearer stars. It would be of great interest to compute the solar motion from stars with still less proper motion than those I have employed. I am glad to know that Professor Boss is now at work on such an investigation, and will doubtless before long be able to throw fresh light on this interesting question.

CINCINNATI OBSERVATORY, Oct. 3, 1892.

STARS HAVING PECULIAR SPECTRA.*

M. FLEMING.

A recent examination of photographs of stellar spectra lately received from the Peruvian station of the Harvard College Observatory and taken under the direction of Professor W. H. Pickering, has added five faint objects, in the constellation Argo, to the list of stars having spectra of the fifth type, and similar to the bright line stars in Cygnus. As forty of these objects have already been announced, this increases the known number to forty-five. The designation of the star, its approximate right ascension and declination for 1900 and its magnitude are given in the first four columns of the following table. The Galactic longitude and latitude are given in the fifth and sixth columns.

Designation.	R. A. 1900 h m	Dec. 1900 ° ′	Magn.	G. Long. ° ′	G. Lat. ° ′
——	10 7.6	−60 8	...	252 4	−3 30
A. G. C. 14691	10 40.3	−59 12	8½	255 48	−0 40
——	10 43.4	−58 41	...	255 20	−0 1
A. G. C. 14965	10 52.0	−59 51	8½	256 49	−0 38
——	10 55.8	−57 17	...	256 16	+1 56

In addition to the stars of the fifth type mentioned above, six new variables have been discovered from the photographs received from Peru and one from those taken in Cambridge during July. Their spectra are of the third type having also the hydrogen lines bright, as is the case in the spectrum of *o* Ceti and other variables of long period. A table of these is here given with further details regarding the measurements following it. The constellation is given in the first column and this is followed by the approximate right ascension and declination for 1900 of the variable. The next two columns give the greatest and least

* Communicated by Edward C. Pickering, Director of the Harvard College Observatory.

brightness as measured from the photographs. The date on which its spectrum was photographed is contained in the last column.

Constellation.	R. A. 1900 h	m	Dec. 1900 °	′	Gr. Br.	Lt. Br.	Date.
Horologium	2	49.7	− 50	21	6.2	9.7	Sept. 10, 1891
Octans	5	56.8	− 86	26	7.4	< 11.3	Sept. 11, 1891
Bootis	14	22.3	+ 5	7	8.2	10.7	April 26, 1892
Libra	15	18.5	− 22	34	8.4	< 11.0	July 25, 1891
Octans	17	25.9	− 86	46	8.2	< 11.7	Aug. 31, 1891
Sagittarius	19	49.7	− 29	26	7.5	< 12.6	Oct. 3, 1881
Tucana	23	52.2	− 65	56	10.2	< 12.6	Aug. 25, 1892

The variable star in Horologium in R. A. 2^h 49.7^m, Dec. — 50° 21′, was measured on photographs taken on Aug. 21, Aug. 25, Aug. 28, Sept. 7, Sept. 26, Nov. 3, 1889, Sept. 8, 1890, Sept. 10 and Sept. 11, 1891, and gave the magnitudes 9.6, 7.5, 7.6, 8.1, 9.3, 9.7, 7.7, 6.2 and 6.2 respectively.

The variable star in Bootis in R. A. 14^h 22.3^m, Dec. + 5° 7′, was measured on photographs taken on May 19, 1890, May 23, 1891, April 26, May 17, May 24, June 6, June 10, June 12, June 15, July 6 and July 21, 1892, and gave the magnitudes 8.8, 8.2, 8.2, 8.4, 8.4, 8.8, 9.1, 8.9, 9.1, 10.0, and 10. 7 respectively.

The variable star in Libra in R. A. 15^h 18.5^m, Dec. — 22° 34′, was measured on photographs taken on June 4, June 7, June 19, July 6, July 12, July 12, July 22, 1889, March 30, May 29, 1890, May 16, May 16, June 3, June 3, June 3, June 25, July 14, 1891, May 24, June 21, July 12, July 18 and July 25, 1892, and gave the magnitudes 9.0, 9.2, 8.6, 8.5, 8.6, 8.6, 8.6, 9.5, < 11.0, 8.5, 8.4, 8.8, 8.9, 8.8, 9.7, 10.4, 9.9, 8.6, 8.6, 8.4 and 8.5 respectively.

The variable star in Sagittarius in R. A. 19^h 49.7^m, Dec. — 29° 26′, was measured on photographs taken on June 10, June 20, July 8, July 21, Aug. 20, Aug. 22, Oct. 7, 1889, May 28, 1890, May 17, May 17, June 2, June 2, Aug. 11, Oct. 3, 1891, July 11, July 25, Aug. 16, Aug. 18 and Aug. 23, 1892, and gave the magnitudes 11.0, < 11.2, < 12.4, 12.4, 12.0, < 10.7, 11.1, 11.7, < 12.2, < 12.6, < 10.7, < 12.2, 11.0, 7.8, 10.8, 10.9, 8.0, 8.0, and 7.5 respectively.

The variable star in Tucana in R. A. 23^h 52.2^m, Dec. — 65° 56′, was measured on photographs taken on Aug. 13, Sept. 20, Oct. 8, Nov. 28, 1889, July 25, Sept. 10, 1890, June 30, Aug. 25, Aug. 25, Sept. 17, Sept. 17, Oct. 4, Oct. 4, Oct. 5 and Oct. 26, 1891 and gave the magnitudes 10.8, < 11.1, < 11.3, < 12.1, < 12.6, < 12.2, < 10.0, 10.6, 10.3, 10.2, 10.3, 10.6, 10.5, 10.5 and 11.0 respectively.

The region including the variable star in Octans in R. A. 5^h 56.8^m Dec. — 86° 26′ was contained on one hundred and five photographs taken between May 9, 1889, and April 26, 1892, its magnitude being about 7.6 on the first date when it was probably near its maximum. At the following minimum it was fainter than the magnitude 11.0. It was again bright on June 22, 1890, and on Aug. 16 and Sept. 3, 1891, when its magnitude was 8.9, 8.2 and 8.2 respectively. Between these two maxima its minimum was fainter than 11.3 and on March 30 and April 26, 1892, it was fainter than the magnitude 10.8.

The region including the variable star in Octans in R. A. 17^h 25.9^m, Dec. — 86° 46′, was contained on eighty-nine photographs taken between May 14, 1889, and April 26, 1892. On Aug. 29, 1889, its magnitude was 8.4 when it was probably near its maximum. At minimum it was fainter than 10.5. It was bright again an April 8, 1890, when its magnitude was 8.5. At minimum it was fainter than 11.7. On Sept. 20, 1891, it again attained the magnitude 8.4 and on March 30, 1892 it was fainter than the magnitude 10.5.

Photographs of the spectra of A. G. C. 9326, R. A. 7^h 14.8^m, Dec. — 36° 33′ (1900), Magn. 5.3, and of A. G. C. 10963, R. A. 8^h 9.7^m, Dec.—35° 35′ (1900), magn. 5.3 taken on April 18, 1892, and on March 16, 1892, respectively, show the F line bright and place them in the same class with δ and μ Centauri.

The magnitudes given above depend on measures derived from the photographs by using the magnitudes of the comparison stars as given in the Argentine General Catalogue. Since all of these variables are probably red stars, as indicated by their class of spectrum, it will be necessary to apply to the magnitudes given above a correction for color before comparing them with magnitudes obtained from visual observations.

Interesting photographs have been obtained of the spectra of the two objects A. G. C. 6744, R. A. 5^h 39.4^m, Dec.—69° 9′ (1900), magn. 6¼, and A. G. C. 20937 R. A. 15^h 21.9^m, Dec. — 24° 49′ (1900), magn. 8. The first of these is the well known gaseous nebula surrounding 30 Doradus. The photograph shows that its spectrum is unlike that of ordinary gaseous nebulæ. A. G. C. 20937 gives a spectrum which appears to be similar and is probably an object of the same class although its nebulous character has not hitherto been suspected. A photograph of the spectrum of G. C. 2581, R. A. 11^h 45.3^m, Dec. — 56° 37′ (1900), magn. 9½, showing bright lines was obtained on Aug. 2, 1892 at Arequipa in Peru. The research which has resulted in the discovery of the above list of objects forms part of the Henry Draper Memorial.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass., Oct. 10, 1892.

THE NEBULAR HYPOTHESIS.*

Continued from p. 570.

We will now project some views on the screen, illustrating the great variety of forms which nebulæ assume.

We have now reviewed such information about the nebulæ as the telescope and the photographic camera can give us; but there is another instrument at the command of the astronomer which has even more wonderful powers than the telescope. You, all know that the spectroscope is an instrument for studying the chemical constitution of a body by means of the light which it emits.

There is not time, within the limits of a single lecture, to explain the principles of spectrum analysis. I will remind you, however, that a glowing gas emits light of certain definite colors only, which going to their appropriate places in the spectrum, and contrasted with the black background due to the absence of other light, appear as bright lines; that a glowing solid or liquid (or greatly compressed gaseous body) gives out light in which all colors are present, forming a continuous spectrum; and that if a cooler gas is placed in front of a luminous solid or liquid body it will absorb some of the light of the latter—just those kinds of rays which the gas is capable of emitting—and the continuous spectrum of the solid will be darkened where the bright lines of the gas would appear if the solid body were removed. Every element has its own characteristic spectrum, which can be recognized either by its appearance or by measurement. It is not possible to consider here all the modifications which should be made of these very general statements.

The spectroscope, when applied to the study of the heavenly bodies, is used in connection with a telescope, as without the latter there would be insufficient light. The spectrum of a nebula was observed with such a combination of instruments for the first time by Dr. Huggins in 1864.

What do we learn about the Andromeda nebula when we direct our spectroscope upon it? The result is disappointing. The spectrum is continuous, and it is very faint. So far, then, the nebula appears to be composed of solid or liquid bodies, but we must be cautious about drawing even this very general conclu-

* A lecture by James E. Keeler, Allegheny Observatory, delivered before the Academy of Science and Art, of Pittsburg, on Nov. 6, 1891.

NOTE.—References to the lantern slides which were exhibited in connection with this lecture have been largely omitted. The list of such illustrations was large, showing the latest and best work done in observing the nebulæ. We are sorry that we can not, as we intended to do, give some of these illustrations.—Ed.

sion. So feeble a continuous spectrum may be due to a gas, even under a moderate pressure. The testimony of the spectroscope is simply inconclusive. It is true that some very slight brightenings have been suspected at two or three places in the continuous spectrum, but, if real, they are so very faint that without further investigation it would be unprofitable to base any conclusions on them.

Here is a magnificent photograph of the Orion nebula, taken by Mr. Common. I may remark that as the different parts of a nebula are of very different degrees of brightness, it is impossible to show the whole object clearly in one photograph. The exposure which is necessary to bring out the faint portions is too great for those that are bright. The exposure of the picture which is on the screen was skillfully chosen so as to show the greatest possible extent of the nebula without obscuring the outlines which are familiar to the eye. Here is another very wonderful photograph, taken at Harvard College Observatory. The exposure was so long that the nebula, as we see it in the telescope, is unrecognizable, but this over-exposed photograph shows that the nebula extends to vastly greater distances than it can be traced by the eye, so that it covers a large part of the great constellation of Orion.

The chief characteristic of the Orion nebula, as compared with the class of nebulæ hitherto considered, is its spectrum, which consists of a number of bright lines. Apparently we have to do, in this case, with an immense mass of glowing vapor, and nebulæ giving a bright line spectrum have been classed as *gaseous nebulæ*.

Scattered through the sky are many nebulæ of this class which present small round discs of a greenish blue color, and from their resemblance to the disc of a planet they were called by Herschel *planetary nebulæ*. The diagram represents the planetary nebula known as G. C. 4390. (No. 4390 in Sir John Herschel's General Catalogue of nebulæ.) It shows a round disc, brightening toward the center, where there is a small star.

Viewed with a large telescope, the structure of a planetary nebula is not always as simple as it appears to be when seen with small optical power. Here is a diagram of the nebula G. C. 4373 from a drawing by Professors Holden and Schaeberle with the Lick telescope. Within the circular nebulous background is what appears at first sight to be a bright double ring, but careful study led the observers to conclude that it is really a great spiral.

As in the nebulæ represented in these diagrams, the middle point of a planetary nebula is usually marked by a small star. With the Lick telescope I have never found an exception, all the nebulæ of this class which I have examined having a star usually exactly in the center.

It is impossible that this critical position of a star should in every case, be the result of chance. There is some connection between the star and the nebula. Is the bright point always found at the center of a real star, or is it a condensation of nebulosity, or are both the same thing?

In the case of G. C. 4390, the stellar point in the center is shown by both the telescope and the spectroscope to be undoubtedly a condensation of nebulous matter, but in other planetary nebulæ it is more like a star, and in some cases it is difficult to say whether the object is a planetary nebula with bright nucleus, or a nebulous star. Some stars, then, at least, are formed by the condensation of nebulosity, for the reverse of the relationship, that the star is the parent of the nebula, is hardly admissible.

It is interesting to note that it was the consideration of this class of objects which led Herschel to conclude (of course long before the spectroscope was invented) that there is a "shining fluid" in space, and that all nebulæ are not, as was then supposed, clusters of stars too remote to be resolved by the telescope. The bright star, he argued, must actually be in the center of the nebula. If, then, the nebula is so remote, the magnitude of the central star must be so great as to transcend all the bounds of probability. On the other hand, if the central point is an ordinary star, comparatively close to us, the bodies which give out the nebulous light must be so small as not properly to be regarded as stars at all. He further regarded this self-luminous matter as "more fit to produce a star by its condensation, than to depend on the star for its existence."

Let us now turn to this colored diagram, representing the spectrum of the planetary nebula G. C. 4390, with a solar spectrum above, for reference. The spectrum consists, as you see, of a number of bright lines, only three of which are conspicuous, and a narrow continuous spectrum due to the nucleus of the nebula. There is also a very faint continuous spectrum from the same part of the nebula which gives the bright lines. The spectrum of the nucleus blends somewhat gradually into that of the nebula, and the bright lines of the latter are greatly strengthened where they cross the continuous spectrum. The spectroscope, therefore, shows conclusively that the central star is really in the nebula, and a part of it.

Does the spectroscope tell us what the substances are that give these bright lines? We observe that three of the lines correspond exactly in position with lines of hydrogen in the solar spectrum above. Beyond the limits of the diagram are other hydrogen lines which have been photographed. Hydrogen, therefore, is certainly an important constituent of the nebulæ. The two brightest lines in the nebular spectrum have not been accounted for. No terrestrial element that we are acquainted with gives lines in exactly the same place. There is some slight evidence that both lines are due to the same substance.

The nebulæ, then, appear to be immense masses of glowing vapor, containing hydrogen and unknown substances. From the character of the lines, the gases seem to be very hot and extremely tenuous.

Mr. Lockyer, the distinguished English spectroscopist, holds a very different view from this. He regards the nebulæ as made up of swarms of meteorites, their luminosity being due to innumerable collisions among the separate particles of the swarm. The brightest of the nebular lines is, according to him, a band or "fluting" due to magnesium, its fluted aspect not being apparent on account of insufficient brightness. It is stated that the magnesium fluting in question appears at low temperature, and hence it is not necessary to consider the nebulæ as intensely heated. This view of Mr. Lockyer's is but a part of a very general hypothesis which he has advanced, covering the whole field of stellar evolution.

Some phenomena presented by the nebulæ are certainly more easily explained by this hypothesis. It is difficult to conceive of the nebulæ as intensely heated, but if we regard them as purely gaseous we must suppose them to be either very hot or else electrically excited, and we have no independent evidence in favor of the latter supposition. On the other hand, the meteoritic hypothesis, so far as the nebulæ are concerned, finds little support in the actual phenomena observed with the spectroscope. With powerful apparatus the brightest nebular line does not agree either in appearance or in position with the fluting of magnesium. Other lines, which should be present according to the hypothesis, are missing. The general testimony of the spectroscope is in favor of the view first mentioned, that the nebulæ are mainly gaseous.

However this may be (and future investigation will probably decide the question), we have seen that in some cases stars are formed by the condensation of this nebulous matter. Is this true of other stars? Have all the stars in the sky been formed in the same way?

It is impossible to answer this question definitely, because so few cases come under our actual observation. In extending our generalizations we are apt to try to make everything conform to one pattern, and not to sufficiently take into account the possibility of fundamental difference of structure. The spectra of such stars as we have considered differ from ordinary stellar spectra, and if the difference is due merely to a progressive change of development, the steps of the process are not obvious. There is, however, evidence to show that condensation of nebulous matter may produce stars of a kind better known. In the beautiful cluster called the Pleiades we have an assemblage of stars, with spectra of the most common type, which in no way seem to differ from other stars in the sky. But only a few years ago the Henry Brothers, of the Paris Observatory, found by photography that the whole background of the Pleiades is nebulous. Faint wisps of nebulousity, so dim that for years they eluded the telescope, cling to the principal stars, and establish beyond doubt the fact of physical connection between the stars and the nebula.

The stars in the trapezium of the nebula of Orion are shown by the spectroscope to be formed from the surrounding nebula, and in other parts of the heavens are stars in various stages of the process of evolution.

Having shown that the stars are formed from nebulæ, we cannot consider that our own Sun, which is nothing more than an average star, is an exception, and of course his retinue of planets, including the Earth, must have been formed by the same process. We thus arrive at the same conclusion which was reached by Kant and La Place, reasoning on different data in the opposite direction. These great philosophers gave independently substantially the same explanation of the phenomena presented by the solar system, before the facts which we have just reviewed were known. That of La Place was the most complete and elaborate, and the "nebular hypothesis" is generally mentioned in connection with his name. It was formed before the great principle of the conservation of energy was discovered, and before it was known that heat and other forms of energy are mutually convertible. Hence some of the details as originally worked out by La Place require modification in the light of present knowledge, although his hypothesis is still the basis of that which is accepted to-day.

Let us see what facts we find in the solar system that are *independent of the laws of gravitation.* I will state them as they are given by Professor Young in his *General Astronomy.*

The orbits of the planets and satellites are all nearly circular.

They are all nearly in one plane.

The revolution of all planets is in the same direction.

There is a regular progression of distances.

There is a regular progression of density.

The plane of the planets' rotation is nearly that of the orbit (except probably Uranus).

The direction of the rotation is the same as that of the orbital revolution (excepting probably Uranus and Neptune).

The plane of orbital revolution of the satellites coincides nearly with that of the planets' rotation.

The direction of the satellites' revolution coincides with that of the planets' rotation.

The largest planets rotate most swiftly.

All these relations cannot be accidental. If the planets had come into the system from outer space, like the comets, they would exhibit every diversity of orbit, rotation, etc., conceivable. We must suppose that the Sun and the planets had a common origin.

La Place took for the beginning of the solar system a nebulous mass at a high temperature, rotating slowly on its axis, and extending beyond the orbit of the farthest planet,—in other words, the *Sun*, before it had contracted to a sphere as great in diameter as the solar system. As the mass contracted, its angular velocity increased, according to a well-known mechanical law, and when the centrifugal force at its boundary balanced the attraction of the central mass, a ring was abandoned, while the rest of the material went on contracting. The ring subsequently contracted into a spherical form, forming a planet, and in the process secondary rings might be abandoned, forming satellites.

According to La Place's hypothesis the outer planets are the oldest, and the Sun is younger than any of the planets.

The theory we have considered must be modified somewhat to explain all the facts of the solar system as we now know them. The satellites of Neptune and Uranus have a *retrograde* motion in their orbits, and it is probable that the rotation of the planet is in the same direction. Again, according to the unmodified hypothesis of La Place, no satellite could revolve in a shorter time than the period of rotation of its primary; but the inner satellite of Mars makes a revolution in only 7½ hours, while the period of the rotation of Mars is about 24 hours. How are these apparently anomalous facts to be accounted for?

Another difficulty in elaborating the details of the hypothesis, is to show how a ring is separated from the parent mass. The particles of material in the solar system, diffused throughout a sphere of such enormous magnitude as to fill the orbit of one of the outer planets, would have little or no cohesion. A series of indefinitely thin rings would apparently be continually separating at the circumference of the nebulous mass, instead of a small number of large rings at great intervals apart.

The following explanation appears to be correct; an exactly uniform distribution of matter in the beginning is improbable; it is much more likely that small variations of density would occur. Denser portions would then become local centers of condensation, and thus it would be possible for the whole mass to separate into a small number of large bodies, instead of a great number of very small ones.

The direction in which one of these large masses would rotate after contraction into a spherical form would depend on the distribution of matter in the mass with respect to the center of motion of the mass as a whole, *i. e.*, to the center of gravity of the whole nebula. The rotation might come out direct, or it might come out retrograde.

In general, then, we should expect a permanent *ring* to be formed only under exceptional conditions of uniform density. We have an example of such a ring in the rings of Saturn,—indeed it was this ring system which first suggested the general explanation.

In regard to the short period of Phobos, the inner satellite of Mars, certain researches of Professor George Darwin show that a retardation of the motion of a satellite, and hence *increase in its orbital velocity* may result from tidal action between a planet and its satellite. The enormous length of time required for such action to produce a perceptible effect need not give us any trouble. Our resources in this direction are unlimited.

We now know that it is not necessary to assume that the original nebulous mass was intensely heated, for in the potential energy of its separated particles we have a sufficient explanation of the present high temperature of the Sun. It is the *shrinkage* of the Sun which still keeps up its supply of heat, although thousands of years would be required to make the diminution of its diameter visible to us. A shrinkage of only 250 feet a year would be sufficient to afford the outflow of heat which we actually see. To show how great the heat resulting from arrested motion may be, I will mention that the falling of the Earth into the Sun would generate nearly 6000 times the quantity of heat that would result from burning it, if it were a solid lump of coal. Falling slowly through resistance, the same amount of heat would be generated, but it would not then be developed suddenly.

Have we, finally (for it is impossible to consider at length all these interesting questions), any evidence in the physical aspect of the planets that they have been evolved in the manner which has been described, or at any rate do we find anything which is inconsistent with this view as to their origin?

In the case of the Earth, there is abundant evidence that the surface has been subjected to vastly higher temperatures in the past than those which prevail at present, and also that the temperature of the interior is still high. The spectroscope shows than the Sun and the Earth are made up of essentially the same substances. There are differences, it is true, but they are not greater than we should expect to find under such dissimilar conditions. According to Professor Rowland, the Earth, if heated up to the temperature of the Sun, would give essentially the same spectrum.

In the largest planets we should expect to find the stage of cooling less advanced, and the density small. This latter condition, at least, actually obtains for the larger planets, for we have:

Density of Jupiter = 1.33.
Density of Saturn = 0.72.
Density of Uranus = 1.22.
Density of Neptune = 1.11.

that of water being 1. The density of the Earth is 5.58.

The physical conditions we have referred to can best be studied by the aid of some views of the planets, Saturn and Jupiter.

On studying the heavens, then, we learn that stars are formed by the condensation of nebulæ, which recent investigations have shown to occupy immense tracts of sky. The high temperature of the stars is a necessary result of the process of contraction. As our own Sun is a star, it is probably formed in the same way. Internal evidence, the phenomena presented by the solar system, is in harmony with the external evidence. The nebular hypothesis unites all the known facts in a manner satisfactory to the reason. Of what wás before the assumed beginning of the origin of the nebula which is the starting point of the hypothesis, science can tell us nothing, and but little more of the end. In the solar system we have, so far as we can tell, a clock which is running down. After a time which has been estimated at something like ten million years, the Sun will have contracted so far that no more shrinkage will be possible, its outflow of light and heat will cease, and all living things must perish. It is, of course, possible that something unseen by our imperfect vision may intervene to avert this dismal end, but with the real beginning and the real end we have nothing to do. The nebular hypothesis is a reasonable explanation of the origin of the solar system as we see it today, by the action of forces which we still see in operation around us, and the limits in time which it considers are finite, though separated by an interval inconceivably vast.

ON THE RELATIVE ALBEDO OF PLANETS.

W. H. S. MONCK.

The results hitherto arrived at with regard to the *albedo* or reflective power of planets (including the Moon) cannot I think be regarded as satisfactory. The reason appears to be that an attempt has been made to determine the absolute *albedo*, and for this purpose a comparison of the Sun's light with that of the planet is necessary. But the disproportion is too great for anything like accurate measurement. Even as compared with the full Moon the intensity of sunlight varies according to different observers between 300,000 to 1 and 800,000 to 1. If we desire more accurate results we must, I apprehend, compare the light of the planets with each other directly.

Supposing that the entire surface of a planet is illuminated and its figure is spherical, the light which it sends us will be proportional to $\frac{a \cdot m^2}{d^2}$ where a is its *albedo*, m its apparent diameter and d its distance from the Sun. (When the whole disc is not illuminated an allowance for the dark part can be easily made.) Then if I_1 and I_2 represent the intensity of the light of two planets photometrically determined, we have:

$$\frac{I_1}{I_2} = \frac{\frac{a_1 \cdot m_1^2}{d_2^1}}{\frac{a_2 \cdot m_2^2}{d_2^2}} \text{; whence again}$$

$$\frac{a_1}{a_2} = \frac{I_1 \cdot m_2^2 \cdot d_1^2}{I_2 \cdot m_1^2 \cdot d_2^2}$$

* Communicated by the author.

(It may be noticed that the value of the fraction $\frac{d_1^2}{d_2^2}$ can be known with much greater accuracy than either d_1 or d_2).

Adopting the *albedo* of any particular planet as our unit we can easily obtain the relative *albedo* of any other planet by this formula provided that we know the value of the fraction $\frac{I_1}{I_2}$. This, I think, Professor Minchin's photo-electric cells when used with a powerful telescope and with adequate precautions, will give us with greater accuracy than any other known method; for according to the observations of the inventor the sensitiveness of the cells is but little affected by the color of the incident light. We shall also, I believe, be able to extend our results from the planets to the Moon—taking care, of course, that the whole light of the planet in the one case and of the moon in the other is falling on the cells. An accurate determination of the relative *albedo* of different planets might lead to important results as regards both their atmospheres and their surfaces. I may remark that if the *albedo* of the Moon is really as low as 0.17 or 0.18—in other words if 82 or 83 per cent of the incident light is absorbed—it is difficult to suppose that the temperature is as low as modern research seems to indicate.

I have assumed that the planets shine by reflected light only and that no light is lost in transmission between the Sun and the planet. On the latter point, it is, I think, pretty certain that there is a loss, but the amount is probably so small as to be inappreciable. In the case of distant fixed stars, however, this loss may attain considerable dimensions.

The light of some of the planets can be easily compared with that of the fixed stars and when the distance of a fixed star is known we could thus compare its brightness with that of the Sun if we knew the absolute *albedo* of the planet. But knowing only the relative *albedo*, one hypothetical element will enter into all our computations. Nevertheless we may be able to make a fair approximation.

THE LUNAR ATMOSPHERE AND THE RECENT OCCULTATION OF JUPITER.*

WILLIAM. H. PICKERING.

According to Schroeter, Gruithuisen, Webb and MM. Henry, one can occasionally with more or less distinctness see a faint lunar twilight prolonging the cusps of the crescent Moon. This twilight, so called, has been frequently seen at Arequipa. It is most conspicuous when the Moon has nearly reached the first quarter, and renders those portions of the dark limb that are situated near the cusps distinctly brighter than the remaining portion. It is best seen with a rather high power, and has been traced either across plains or upon distant mountains to a distance of sixty seconds of arc. This distance upon the Moon would correspond to a difference of latitude amounting to four degrees. The terrestrial twilight extends through about eighteen degrees, which indicates that there is matter capable of dispersing the Sun's light at an altitude above the Earth of about forty miles.†

According to the Greenwich observations of occultations, if we assume the diameter of the Moon accurately known, the lunar atmospheric refraction amounts to about 2″. Based upon this figure Neison says, "At present it can be taken with some degree of probability that the density of the lunar atmosphere does not differ much from between three and four hundredths of that of the Earth's." * * *

In the SIDEREAL MESSENGER for April, 1890, I published a paper upon some photographs taken at the Boyden Station in California during an occultation of Jupiter. Unfortunately I have not a copy of that paper with me, but the point of particular interest in this connection was that measurements were made of the diameters of Jupiter just after occultation, and that a slight flattening was detected in the direction of the lunar radius due presumably to refraction by the lunar atmosphere. This flattening, if I remember correctly, indicated for the atmosphere a density not far from one four-thousandth of that of the Earth.

At the recent occultation of August 12, these photographs were repeated under much more favorable conditions, and the flattening of the disc of Jupiter again measured. Satisfactory negatives were obtained both immediately before and immedi-

* Communicated by the author.

† A. C. Ranyard in *Knowledge*, Nov. 1891, p. 213.

ately after the occultation. It was found from these measurements that the refraction produced by the lunar atmosphere certainly did not exceed one second, and probably not one-half of a second of arc. This result is considerably smaller than that given by the Greenwich star occultations, but, as was stated at the time that they were published, their value is probably too large by an unknown quantity, depending upon our lack of information as to the true diameter of the Moon. Adopting these latest observations, the density of the lunar atmosphere can not exceed one four-thousandth, and probably not one eight-thousandth of that of the Earth. It would, therefore, be equivalent to a pressure of about $\frac{1}{250}$ of an inch of mercury at the surface. Although this value seems small, it is by no means insignificant, and would correspond to a pressure of hundreds of tons per square mile of the lunar surface.

In the case of the Earth, the atmospheric pressure is reduced one-half by an ascent of every three and a half miles. Thus at an altitude of seven miles the pressure is but one quarter of that at sea level. On the Moon, however, owing to the diminished force of gravity, we must ascend to an altitude of twenty-one miles in order to reduce the atmospheric pressure one-half. It will thus be seen that the temperature of the lunar summits cannot differ greatly from that of the lunar plains, a result indeed which is more or less confirmed by the researches of Professor Very. It has been suggested that the comparative whiteness of the lunar summits was due to the presence of snow. We should not, however, expect the difference of temperature between them and the lunar plains to be greater than that produced by an increase of elevation of three or four thousand feet upon the Earth.

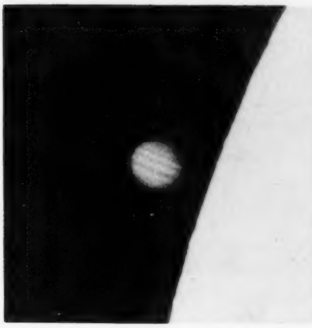
It has been found that shooting stars and meteors upon entering our atmosphere first become luminous at an altitude of about eighty miles. The barometric pressure at this altitude, at 0°, is found by computation to be $\frac{4}{1000000}$ of an inch. In the night time with a lower temperature, the pressure must be much less. It will therefore be seen that the lunar atmosphere is quite sufficient to render luminous and destroy all the smaller meteors before they can strike the surface. Indeed the atmospheric pressure at the Moon's surface as determined by the photographs of the recent occultation should be about equal to, but not much exceed, that at forty-five miles above the surface of the Earth. But we have already seen that the Earth's atmosphere at an altitude of forty miles above the surface is capable of producing the phenomenon of twilight. If the lunar twilight described at the beginning of this paper is a genuine phenomenon, we should then expect that the lunar atmosphere at an altitude of one or two miles above the surface should be about equal to that of the Earth at an altitude of forty miles. The two results agree quite within the limits of accuracy of the observations.

Owing to the slow diminution of pressure in the Moon's atmosphere, we find that at an altitude of fifty-three miles, the lunar and terrestrial atmospheres have the same density, and that above that point the lunar atmosphere is actually the denser of the two. Owing to this circumstance its atmosphere rises to a considerably greater height than does that of the Earth, shooting stars upon the Moon first becoming luminous at an altitude of about two hundred and ten miles.

In the photograph taken when Jupiter was half concealed by the bright limb of the Moon, a dark band three seconds in breadth is seen stretching across the face of the planet, tangent to the Moon's limb. This dark band was also observed visually. When Jupiter reappeared from behind the dark limb of the planet no such band was seen, nor does it appear upon the photographs. Since this band was photographed it cannot well be due to an optical illusion, and since it was seen it can hardly be classed as a photographic defect,—unless indeed we suppose that by a coincidence both conspired to produce the same result. The visual observations were made by Mr. Douglass, who employed a five-inch refractor with a power of seventy-five diameters. A ray of light tangent to the Moon's limb would pass through 160 miles of its atmosphere before it reached an altitude of 3″ as seen from the Earth. Unless this atmosphere contained some dust or moisture in the form of cloud, it would hardly seem sufficient to produce the absorption observed. If the absorption were due to moisture, it would naturally not be seen upon the dark limb, as it would be condensed and precipitated by the cold.

It is sometimes referred to as a singular fact that the lunar atmosphere should be so rare. It is possible, however, that an explanation may be found for this phenomenon. If we adopt Professor Darwin's ingenious hypothesis that the Moon once formed part of the Earth, we may fairly assume that when the two bodies parted company they divided their common atmosphere equally between them, in proportion to their respective masses. Since the Moon's mass is to that of the Earth as 1 to 81.4, and its surface as 1 to 13.5, its atmosphere would then have contained almost exactly one-sixth as many molecules per square mile as that of the Earth. But since the force of gravity

PLATE XXXVIII.



1

2

3

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Photographs of Jupiter at the Occultation of August 12, 1892

Taken by Professor Wm. H. Pickering at Arequipa, Peru.

at the Moon's surface is also one-sixth of that at the surface of the Earth, the density of the lunar atmosphere must have been one thirty-sixth of that of the Earth. This would correspond to a pressure of 0.83 inches of mercury at the Earth's surface, and we should not under any circumstances expect to find a lunar atmosphere of greater density than this.

If a particle should fall upon the Moon from an infinite distance acted upon solely by the Moon's gravity, it would acquire a velocity of 1.5 miles per second. And conversely, if thrown from the Moon with this velocity, it would never return.

According to the researches of Professors Langley and Very, the temperature of the Moon's surface may be taken at about 0° centigrade. There is no reason to suppose that any particle situated in the immediate vicinity of the Earth's orbit, would possess a much lower temperature than this, if exposed to the Sun's rays. At this temperature the molecules of nitrogen composing our atmosphere have a mean velocity of rather less than one-third of a mile per second, and the molecules of oxygen a mean velocity of rather more than one quarter of a mile. These are their mean velocities, but some of these particles are undoubtedly moving at a very much slower rate than this, and some a great deal faster. When there are many of them they are changing their velocities millions of times every second, owing to mutual collisions. But where there are only comparatively few of them as would be the case, for instance, near the outskirts of the lunar atmosphere, it would frequently happen that one of these molecules possessing five or six times the average velocity of the rest would not meet any other molecule in its path to stop it, and it would then be carried away from the Moon never to return to it again, unless brought back by the attraction of some other outside body such as the Earth or the Sun. We thus see that even now the Moon must be constantly losing whatever atmosphere it possesses, while it has no means whatever of recovering it.

This course of reasoning does not apply to the same extent to the Earth, for owing to its greater mass, a molecule to escape from its grasp must have a velocity of very nearly seven miles per second. It must be a rare thing for a molecule to have twenty times the mean velocity of its neighbors, and therefore if we are losing our atmosphere at all from this cause, it must be taking place very slowly indeed. If our atmosphere instead of consisting of oxygen and nitrogen, had been made up wholly of hydrogen gas, it would have been a very different matter. At a temperature of 0° the mean velocity of the hydrogen molecules is over a mile per second, and any molecule having six times the mean velocity of its fellows, and not suffering from a collision, would be carried away from the Earth never to return. Thus at the present time it would be quite impossible for the Earth to retain for a long period a dense atmosphere of hydrogen gas. If this is the case at present it must have been still more markedly so in pre-geological times, if the Sun were then hotter, because the latter would then have been able to maintain the hydrogen molecules exposed to its rays at a temperature higher than 0°, and their velocities would therefore have been still greater. Under these circumstances the question arises whether the temperature of the Earth could then have been high enough to disassociate steam into its component gases. It does not seem as if the temperature of the Earth and Moon could have been as great as this when they parted company, for we find apparently evidences of the action of water upon the surface of the latter, and we can hardly conceive of a volcanic eruption without the presence of some water.

It will thus be seen that only upon large bodies could we expect to find an atmosphere of hydrogen gas, unless the body is located in a portion of space where the temperature is very low. Also that upon small bodies like our Moon, we should expect to find the proportion of oxygen and carbonic acid in the atmosphere greater than with us, and that their atmospheres would also be less dense. This course of reasoning applies with less force to the planet Mars, since being at a greater distance from the Sun, the velocity of the outer molecules of its atmosphere would be materially diminished, still it would not surprise us to find that it possessed less water and less atmosphere than the Earth. The condition of Venus is similar to that of the Earth, but with Mercury quite a new condition of affairs arises. At perihelion distance this planet receives from the Sun ten times as much heat per square mile as does the Earth. Since the velocities of the molecules of a gas increase as the square roots of their absolute temperatures, it will be seen that notwithstanding its considerable density, it would be quite impossible for this planet to retain any atmosphere at all comparable with that of our Earth. I may add that our observations upon the length of the cusps of Mercury made in Arequipa entirely confirm this view.

AREQUIPA, Peru, Aug. 29, 1892.

A LARGE SOUTHERN TELESCOPE.

PROFESSOR EDWARD C. PICKERING.

The wide interest in astronomical research is well illustrated by the freqent gifts of large telescopes to astronomical observatories by wealthy donors who are not themselves professional students of astronomy. The number of these gifts is continually increasing, and in no department of science has greater liberality been displayed. Unfortunately, the wisdom shown in the selection of good locations for the telescopes has not equalled the generosity with which they have been given. Political or personal reasons, rather than the most favorable atmospheric conditions, have in almost all cases determined the site. These telescopes have been erected near the capitals of countries or near large universities, instead of in places where the meteorological conditions would permit the best results to be obtained. The very conditions of climate which render a country or city great, are often those which are unfavorable to astronomical work. The climate of western Europe and of the eastern portion of the United States is not suited to good astronomical work, and yet these are the very countries where nearly all the largest observatories of the world are situated. The great number of telescopes thus concentrated renders it extremely difficult for a new one to find a useful line of work. The donor may therefore be disappointed to find so small a return for his expenditure, and the opinion has become prevalent that we cannot expect much further progress in astronomy by means of instruments like those now in use. The imperfections of our atmosphere appear to limit our powers, and are more troublesome relatively with a large than with a small telescope. Accordingly, it has not been the policy of the Harvard College Observatory to attempt to obtain a large telescope to be erected in Cambridge. In order to secure the greatest possible scientific return for its expenditures, large pieces of routine work have by preference been undertaken, which could be done with smaller instruments. These conditions are now, however, changed. A station has been established by this Observatory near Arequipa in Peru, at an altitude of more than eight thousand feet. During a large part of the year the sky of Arequipa is nearly cloudless. A telescope having an aperture of thirteen inches has been erected there, and has shown a remarkable degree of steadiness in the atmosphere. Night after night atmospheric conditions prevail which occur only at rare intervals, if ever, in Cambridge. Several of the diffraction rings surrounding the brighter stars are visible, close doubles in which the components are much less than a second apart are readily separated, and powers can be constantly employed which are so high as to be almost useless in Cambridge. In many researches the gain is as great as if the aperture of the instrument was doubled. Another important advantage of this station is that, as it is sixteen degrees south of the Equator, the southern stars are all visible. A few years ago a list was published of all the refracting telescopes having an aperture of 9.8 inches or more (SIDEREAL MESSENGER, 1884, p. 193). From this it appears that nearly all of the largest telescopes are north of latitude + 35°, although this region covers but little more than one-fifth of the entire surface of the Earth. None of the seventeen largest and but one of the fifty-three largest telescopes are south of this region. Of the entire list of seventy-four, but four, having diameters of 15, 11, 10, and 10 inches, are south of + 35°. The four largest telescopes north of + 35° have apertures of 36, 30, 29, and 27 inches respectively. But few telescopes of the largest size have been erected since this list was prepared, and the proportion north and south is still about the same. It therefore appears that about one quarter of the entire sky is either invisible to, or so low that it cannot be advantageously observed by, any large telescope. The Magellanic clouds, the great clusters in Centaurus, Tucana, and Dorado, the variable star η Argus, and the dense portions of the Milky Way, in Scorpius, Argo, and Crux, are included in this neglected region. Moreover, the planet Mars, when nearest the Earth, is always far south. The study of the surface of this and of the other planets is greatly impeded by the unsteadiness of the air at most of the existing observatories. Even under the most favorable circumstances startling discoveries—relating, for example, to the existence of inhabitants in the planets—are not to be expected. Still it is believed that in no other way are we so likely to add to our knowledge of planetary detail as by the plan here proposed. The great aperture and focal length and the steadiness of the air will permit unusually high magnifying powers to be employed, and will give this instrument corresponding advantages in many directions,—for instance, in micrometric measures, especially of faint objects. It can be used equally for visual and photographic purposes, and in photographing clusters, small nebulæ, double stars, the Moon, and the planets, it will have unequalled advantages.

A series of telescopes of the largest size (including four of the six largest, the telescopes of the Lick, Pulkowa, U. S. Naval, and McCormick observatories) has been successfully constructed by the firm of Alvan Clark and Sons. But one member of the firm now survives, Mr. Alvan G. Clark; and he expresses a doubt whether he would be ready to undertake the construction of more than one large telescope in the future. The glass is obtained with difficulty and often only after a delay of years. A pair of discs of excellent glass suitable for a telescope having an aperture of forty inches has been cast, and can now probably be purchased at cost, $16,000. The expense of grinding and mounting would be $92,000. A suitable building would cost at least $40,000. If the sum of $200,000 could be provided it would permit the construction of this telescope, its erection in Peru, and the means of keeping it at work for several years. Subsequently, the other funds of this Observatory would secure its permanent employment. Since a station is already established by this Observatory in Peru, a great saving could be effected in supervision and similar expenses, which otherwise would render a much larger outlay necessary.

An opportunity is thus offered to a donor to have his name permanently attached to a refracting telescope which besides being the largest in the world would be more favorably situated than almost any other, and would have a field of work comparatively new. The numerous gifts to this Observatory by residents of Boston and its vicinity prevent the request for a general subscription; but it is believed that if the matter is properly presented, some wealthy person may be found who would gladly make the requisite gift, in view of the strong probability that it will lead to a great advance in our knowledge of the heavenly bodies. Any one interested in this plan is invited to address the undersigned.

CAMBRIDGE, MASS,, U. S. A., September 1892.

GROUPS OF ASTEROIDS.*

PROFESSOR DANIEL KIRKWOOD.

The conjecture of Dr. Olbers was not unnatural when in 1802 a second asteroid was found, having nearly the same distance from the Sun as Ceres. The nebular hypothesis had not then taken the scientific place which it soon afterward gained. The phenom-

* Communicated by the author.

ena of two planets with intersecting orbits had been hitherto unknown. The clustering planetoids of the opening century had awakened a bold conjecture which was not wholly abandoned for many years to come. When the number of telescopic planets, however, had grown to hundreds, and when the perihelion distance of some had become greater by many millions of miles than the aphelion of others—the theory of explosion was necessarily abandoned. But the doctrine of a *similarity* of origin was not so easily disposed of. The original dimensions of nebulous asteroids were probably many times greater than those of the present. The disrupting tendency of the great bodies of the system, especially when resisted only by the slight central attraction of nebulous asteroids, is easily imagined. Such separation, in short, has no improbability whatever. The dismemberment of comets, as is well known, has actually occurred under our own eyes. Why not also the pulling asunder of nebulous planets?

The fact that in many cases the motions of asteroids indicate a common origin, affords strong presumptive evidence in favor of the nebular hypothesis. Possibly, indeed, its true form may have differed from that proposed by La Place. The ancient dismemberment of Vera, 245, and Semele, 86, for instance, is infinitely more probable than the violent explosion of Ceres and Pallas as consolidated planets. The elements of the former, as has been shown, are almost exactly coincident. But these are only specimens of eighty similar cases. How many primitive, *separate* nebulæ were contained in our system, and how many of these primitive masses suffered dismemberment while Mars and the then future earth were yet floating in the solar atmosphere, cannot now be told. An indefinite number, however, may undoubtedly be traced. May not similar processes be also indicated in the slow evolution of binary and multiple stars in the sidereal heavens?

The following table includes several groups by M. Tisserand, of Paris, and Mr. Monck, of Dublin, as well as those given by the author in the *Publications of the Astronomical Society of the Pacific*. It contains over eighty members of groups—the largest number yet published:

NOTES:

1. The distance from the outer margin of the gap at 3.27 to the orbit of Thule, 4.27, is unity. The number of asteroids now known in this section is 13, nine of which are included in the four outer groups. From the inner margin at 3.22 to the ring's interior edge is a distance of 1.05, only slightly greater than the

breadth of the outer ring, but containing 317 asteroids—24 times the number in the outer section.

2. A remarkable clustering tendency is found from 3.16 to 3.08; a group of five occurring in a narrow strip whose breadth is but 0.0162. This remarkable group is where we find the relation

$$n^{(a)} - 3n^{V} + 2n^{VI} = 0;\ \text{or}\ n^{(a)} = 656''.4 \pm$$

Other similar sections may be found in like manner.

a represents the mean distace; *e* the eccentricity; *i* the inclination; *π* the longitude of the perihelion.

GROUPS OF ASTEROIDS.

	Name	*a*	*e*	*i* °	*i* ′	*π* °	*π* ′
	1						
153	Hilda	3.9538	0.1641	7	52	285	29
190	Ismene	3.9471	0.1634	6	7	105	39
	2						
107	Camilla	3.4847	0.0756	9	54	115	53
87	Sylvia	3.4833	0.0922	10	55	333	48
	3						
260	Huberta	3.4586	0.1103	6	16	329	45
121	Hermione	3.4535	0.1254	7	36	357	50
	4						
65	Maximiliana	3.4339	0.1062	3	29	259	54
76	Freia	3.4140	0.1699	2	3	90	49
229	Adelinda	3.4059	0.1518	2	10	333	37
	5						
122	Gerda	3.2177	0.0415	1	37	203	45
300	Geraldina	3.2083	0.0423	0	47	331	1
	6						
154	Bertha	3.1976	0.0787	20	59	190	47
286	Iclea	3.1942	0.0123	17	57	352	40
	7						
92	Undina	3.1851	0.1024	9	57	331	27
297	Cecilia	3.1752	0.1450	7	31	329	2
	8						
106	Dione	3.1670	0.1788	4	38	25	57
104	Clymene	3.1556	0.1470	2	53	62	30
171	Ophelia	3.1554	0.1142	2	33	148	31
	9						
94	Aurora	3.1602	0.0827	8	4	48	46
252	Clementina	3.1552	0.0837	10	2	355	8
	10						
250	Bettina	3.1524	0.1303	12	54	87	28
57	Mnemosyne	3.1510	0.1145	15	24	53	25
	11						
62	Erato	3.1241	0.1756	2	12	39	0
257	Silesia	3.1190	0.1217	3	40	65	16
212	Medea	3.1157	0.1013	4	16	56	18

•	Name	a	e	i °	i ′	π °	π ′
	12						
86	Semele	3.1015	0.2193	4	47	29	10
305		3.0973	0.1927	4	26	104	37
245	Vera	3.0966	0.1975	5	11	27	48
223	Rosa	3.0937	0.1206	1	59	106	35
268	Adorea	3.0853	0.1285	2	25	184	48
	13						
280	Philia	2.9722	0.1374	7	22	10	56
179	Clytemnestra	2.9711	0.1133	7	47	355	39
	14						
22	Calliope	2.9090	0.1012	13	45	59	58
238	Hypatia	2.9081	0.0876	12	23	28	24
191	Kolga	2.8967	0.0876	11	29	23	21
	15						
235	Carolina	2.8795	0.0595	9	4	268	29
195	Euryclea	2.8790	0.0471	7	1	115	48
	16						
158	Coronis	2.8714	0.0548	1	0	56	56
243	Ida	2.8609	0.0419	1	10	7	22
167	Urda	2.8533	0.0340	2	11	296	4
	17						
264	Libussa	2.7963	0.1380	10	27	26	39
28	Bellona	2.7800	0.1491	9	22	124	1
	18						
1	Ceres	2.7693	0.0763	10	37	149	38
237	Cœlestina	2.7607	0.0738	9	46	282	49
	19						
116	Sirona	2.7669	0.1433	3	35	152	47
55	Pandora	2.7604	0.1429	7	14	10	36
278	Pauline	2.7575	0.1331	7	50	199	52
213	Lilæa	2.7563	0.1437	6	47	281	4
	20						
203	Pompeia	2.7376	0.0588	3	13	42	51
160	Una	2.7287	0.0624	3	51	55	57
301	Bavaria	2.7258	0.0660	4	53	24	4
	21						
103	Hera	2.7014	0.0803	5	24	321	3
58	Concordia	2.7004	0.0426	5	2	189	10
	22						
123	Brunhilda	2.6950	0.1232	6	25	69	25
34	Circe	2.6865	0.1073	5	27	148	41
	23						
249	Asporina	2.6947	0.1050	15	35	256	6
218	Bianca	2.6653	0.1155	15	13	230	14
	24						
66	Maia	2.6454	0.1758	3	6	48	8
37	Fides	2.6440	0.1750	3	7	66	26
	25						
53	Calypso	2.6175	0.2060	5	7	92	52
269	Justitia	2.6167	0.2024	5	25	274	38
	26						
119	Althea	2.5824	0.0815	5	45	11	29
32	Pomona	2.5873	0.0830	5	29	193	22

	Name	a	e	i °	i ′	π °	π ′
	27						
79	Eurynome	2.4436	0.1945	4	37	44	22
19	Fortuna	2.4413	0.1594	1	33	31	3
	28						
249	Ilse	2.3793	0.2195	9	22	14	16
115	Thyra	2.3791	0.1939	11	35	43	2
84	Clio	2.3629	0.2360	9	40	339	20
	29						
306	Unitas	2.3623	0.1515	7	14	305	48
169	Lelia	2.3577	0.1313	5	31	326	20
163	Erigone	2.3560	0.1567	4	42	93	46
	30						
219	Thusnelda	2.3542	0.2247	10	47	340	34
220	Stephania	2.3505	0.2571	7	34	333	36
12	Victoria	2.3342	0.2189	8	23	301	39
284	Amelia	2.3532	0.2195	8	5	288	57
18	Melpomene	2.2956	0.2197	10	9	15	5
	31						
207	Hedda	2.2838	0.0301	3	49	217	2
40	Harmonia	2.2673	0.0466	4	16	0	54
	32						
270	Anahita	2.1976	0.1501	2	26	332	23
281	Lucretia	2.1859	0.1322	5	19	45	36
244	Sita	2.1765	0.1370	2	50	13	8

Formation of the Baltimore Astronomical Society.—The Baltimore Astronomical Society, which was organized in this city on September 6th, held its first regular meeting at No. 323 North Charles street. The society is in its infancy, and is composed of amateur scientists, who devote much time to the study of the planets. There were twenty persons present at the meeting. The officers of the society are George Gildersleeve, president; Dr. J. R. Hooper, vice president; Justice Stahn, secretary, and William Numsen, treasurer. The members of the society who have observatories are as follows: George Gildersleeve, observatory on North Charles street, consists of 6-inch telescope, made by Dr. Hastings. Most of his observations are confined to the Sun, and he possesses records of spots on the Sun, all double stars and comets seen for the last fifteen years. Dr. J. R. Hooper's observatory is on Lincoln avenue, and consists of a 5-inch Clark telescope. Comets are his pet subjects of observation. Dr. Clark is also the possessor of the 4-inch telescope used at the Eclipse expedition in 1884, by Dr. Hasting who at that time was connected with the John Hopkins University. William Numsen's observatory is located at Arlington, and has a 4-inch Cook telescope. Wm. Pitt's observatory on St Paul street is equipped with 6-inch refractor and reflector, and two small telescopes. Mr. Justice Stahn, the secretary of the society has an observatory at his home on Ensor street, where he uses a 4½-inch refractor and spectroscope.

The society will hold meetings once a month.

ASTRO-PHYSICS.

THE YERKES OBSERVATORY OF THE UNIVERSITY OF CHICAGO.*

GEORGE E. HALE, DIRECTOR.

Through the munificence of Charles T. Yerkes of Chicago, the University of Chicago is to have an astronomical observatory of the first class. Indeed, it is Mr. Yerkes' express desire that in every particular the new observatory shall as nearly as possible attain the existing ideas of perfection. No definite limit has as yet been assigned to the expenditure contemplated, but the generosity of the donor is fully indicated by his wish that the completed observatory shall be second to none.

The aperture of the great telescope, which will form the central feature of the establishment, will shortly be decided upon in accordance with the condition that it must surpass that of the largest existing instrument—the 36-inch refractor of the Lick Observatory. It is probable that a size between 40 and 45 inches will be selected. A pair of 40-inch discs of glass, which were made some time ago for the University of Southern California, are now for sale, and these may possibly be obtained. Should they be secured, some time would be saved in completing the telescope, but it is not altogether certain that they will be considered large enough by the liberal donor.

The mounting of the telescope is already under discussion, and its general features have been decided upon. The quick and slow motions of the telescope, clamping in right ascension and declination, rise and fall of the floor upon which the observer stands, rotation of the dome, etc., will all be operated by electric push-buttons within easy reach of the astronomer at the eye-end of the instrument. They will also be under the control of an assistant seated at a table on the rising floor. Electric devices for operating large telescopes have not hitherto been employed, even on the great Lick telescope. They were long ago suggested, however, notably by Sir Howard Grubb and Dr. David Gill.

The diameter of the dome will naturally depend upon the focal length of the telescope, but it will probably be in the neighborhood of 85 feet. As in the case of the Lick Observatory and the new Naval Observatory at Washington, the entire floor of the observing room will be made to rise and fall by means of hydraulic rams. The cumbrous observing chair once in vogue is

* Communicated by the author.

thus done away with, and the utmost convenience to the astronomer secured.

The remainder of the observatory's equipment is still undetermined, but it will probably include a 16-inch refractor, 12-inch "twin" equatorial, with visual and photographic objectives, 6-inch meridian circle, and 20-inch siderostat.

But the equipment of an observatory is only a means to an end. Many an instance could be cited of an elaborate collection of instruments lying almost unused, or at best contributing little or nothing to the advancement of science. It is intended that the Yerkes Observatory shall be devoted to investigation, and even at this early day an outline of the work which may profitably be undertaken will not be without interest.

It is of the first importance that the exceptional instrumental equipment of the new observatory shall not be wasted by a mere duplication of work done equally well elsewhere. Evidently a telescope of the great aperture contemplated should not be employed in the observation of objects within easy reach of much smaller instruments. This principle was steadfastly adhered to by Mr. Burnham in all of his work with the great Lick refractor. Wide and easy double stars were passed over, and the whole time devoted to the discovery and measurement of extremely difficult pairs. In the field of general research the Yerkes telescope should be applied to the search for new satellites, the study of faint and difficult details of planetary markings, the measurement of Burnham's more difficult doubles, and many similar observations. In stellar spectroscopy a great opportunity will be open, for the immense light-grasping power of the new objective will allow the spectra of stars now beyond our reach to be investigated. The work so ably begun by Keeler at the Lick Observatory, on the spectra and motions of the planetary nebulæ, should be continued and extended. A new departure in the work of large observatories will be the inauguration of a more extensive study of the Sun than has previously been undertaken. This department will be the special province of the writer, and plans for the work have been fully matured.

It is safe to say that an unprejudiced student, in examining the various classes of work pursued by astronomers, would be struck by the small attention given to solar investigation. It is true that in 1869 there was a great awakening of interest in the study of solar spots and prominences, due to the novel methods of spectroscopic research which had just been introduced. But, outside of Italy, there are but two or three observatories which at the present time make a systematic record of solar phenomena. One of these is in England, another in Hungary, and in this country there is one. Fragmentary records are kept elsewhere, but while important, they do not admit of a well-balanced study of the Sun. In Italy the subject has received more attention, and the *Societa degli Spettroscopisti Italiani* (the only existing society of spectroscopists) has faithfully preserved the traditions of Secchi and his associates. Under the leadership of Professor Tacchini, this society seems fully to realize the importance of closely investigating the only one of all the stars which is near enough the Earth to be examined in detail. But in spite of their untiring labors, and the cloudless blue of their propitious skies, it is possible to greatly extend the work of the Italian observers. And this for two reasons. In the first place, their instrumental equipment includes no telescopes of very large size, and in the second, photographic methods have not yet been introduced into their researches. In view of this latter point especially, it is easy to see what possibilities lie open to the solar department of the Yerkes Observatory. In applying on a large scale the photographic methods devised and now in use at the Kenwood Observatory, and in adding to and extending them, it will for the first time be possible to completely investigate every variety of solar phenomena. The corona should perhaps be excepted, but it is not altogether impossible that a new instrument now being constructed at the Kenwood Observatory for the purpose of photographing it in full sunlight may prove a success. With an automatic apparatus, also devised here recently, photographs of the Sun, showing all of the phenomena of its surface, will be taken at intervals of about five minutes throughout the day. Photographs will also be taken at frequent intervals with a 12-inch photographic objective and amplifying lens, showing the Sun on a scale of about four inches to the diameter, and others of individual spots on a scale of sixteen inches to the diameter. A spectroheliograph will be so attached to the great telescope that photographs of groups of faculæ and prominences may be taken on a scale of about seven inches to the Sun's diameter, and also, by the use of an amplifying lens, on a scale of sixteen inches to the diameter. These photographic observations will be supplemented by simultaneous visual observations, and the spectra of faculæ, spots and prominences will be investigated both photographically and visually. Various special investigations on the Sun will also be undertaken, and the records of self-registering magnetic instruments will assist in the solution of the perplexing question as to the relation existing between solar and terrestrial phenomena.

The astronomers who are to be in charge of the other departments of work having not yet been appointed, no more definite plans can at present be formulated for the investigations other than solar. It is hoped that the importance of the Observatory will be measured rather by its work than by its instruments, and that the expectations naturally raised by so perfect an equipment will not be disappointed.

KENWOOD OBSERVATORY, University of Chicago,
Oct. 17, 1892.

NOTE ON SPECTROSCOPIC INVESTIGATIONS AT THE PHYSICAL INSTITUTION OF THE ROYAL SWEDISH ACADEMY OF SCIENCES.*

PROFESSOR B. HASSELBERG.

Among the works on spectrum analysis which as a necessary complement followed the fundamental investigations of Angström upon the solar spectrum, the researches of Thalén on the emission spectra of metals have long occupied a prominent place. And this with every reason, for these researches not only represent the first really scientific inquiry on this subject, but also laid the first solid ground for the physical interpretation of solar and stellar spectra generally. For their epoch these two works are to be regarded as the very corner stone, indeed, of the whole growing science of astro-physics. The immense progress which in some twenty years since then elapsed has been made in the construction of the spectroscope, together with the introduction of modern photography in spectroscopy, could not but totally transform this field of science, and thus we now not only find ourselves confronted by a great many questions then not raised, but also are in possession of most powerful means for their solution.

The chief effect of the improved spectroscope was to show the possibility of greatly improving upon the normal solar spectrum as given by Angström, not only in regard to completeness but above all as to precision of absolute determination of wave-lengths. The successive steps taken in this direction by Cornu, Vogel, Fievez, Müller and Kempf, Thollon, and more re-

* Communicated by the author.

cently by Rowland in his magnificent photographic chart of the solar spectrum, I scarcely need to point out here. Indeed this Atlas, together with the unprecedented diffraction gratings which Rowland has put in the hands of spectroscopists of to-day, have, I think, so totally and profoundly changed the whole face of spectroscopic research that almost everything previously done is to be gone over again before any real progress in its application to molecular and stellar physics can be made. This is especially the case with the emission-spectroscopy of the chemical elements, in which the progress since Thalén has been slow and by no means comparable with the advancement in our knowledge of the structure of the solar spectrum, and the accuracy with which the wave-lengths of the lines contained therein are now determined.

From this point of view I have undertaken a detailed revision of the metallic spectra as they appear in the voltaic arc. A similar series of researches is, as is well known to spectroscopists, also in progress at Hannover, Germany, where Professors Kayser and Runge are making very thorough investigations on this subject, but without special attention to the elimination of foreign lines from the spectra. Although I am fully aware of the extraordinary difficulty connected with such an elimination, and do by no means hope herein to reach perfection, I think it nevertheless, worth while to try it in the hope thus at least to diminish the almost insupportable confusion which now prevails in this branch of spectroscopy.

As stated by Professors Kayser and Runge, the main scope of their researches is to find harmonic series of lines in the spectra of the elements, and thus to create a solid basis for the spectroscopic study of molecular physics. My researches are following up a somewhat different line namely, to give the means for a more accurate investigation of solar and stellar chemistry. In regard to this application of spectroscopy to astronomy the present state of science must be acknowledged as lamentably imperfect, indeed not only with reference to the Sun, of whose spectral lines only a small part are as yet identified with sufficient certitude, but, above all with reference to the stars. As an instance of this the fact may be mentioned that, notwithstanding the great accuracy now obtainable in the measurement of photographic spectra of stars, no reliable inference can be made therefrom as to their chemical constitution, on account of our present ignorance of the structure of the spectra of the chemical elements, and the utterly insufficient accuracy in the position of their lines. It is also next to certainty that much of the latest speculation in stellar physics will break down as soon as the spectra of the chemical elements become known with an accuracy of the same order as the solar spectrum.

For the execution of this plan—which, of course, was also the leading principle of the work at the astro-physical laboratory under my charge at the Pulkowa Observatory—the physical institution of the Academy had to be equipped with new and adequate installations for spectroscopy and photography of the highest possible order. Up to the year 1889, when the direction of this institution was intrusted to me, the work carried on there had been chiefly electrical, under the direction of the late Professor Edlund; and thus it is plain that for the new purposes the necessary experimental means could not be available. My next task was then to supply this want, and, as proved by the work already done, the apparatus and appliances acquired are in every way satisfactory. First among these are to be named the excellent Rowland gratings obtained from the workshops of Brashear in Allegheny. A flat grating of 4 inches and 14,438 lines to the inch forms the dispersive part of the large spectrograph ordinarily used. As collimator to this instrument a Steinheil 3½-inch refractor is employed and a similar objective as camera lens. The focal lengths of these objectives are 1.5 metres. The grating is supported by the horizontal circle of a transit instrument, thus enabling the observer to bring the different spectra into the field of view by turning the grating, while the collimator and camera are fixed at about 40° to one another. The excellent performance of this instrument, and the special peculiarities of the spectra given by it, have been fully described in my memoir on the absorption spectrum of bromine.* A great 6-inch concave Rowland grating with 20,000 lines to the inch will also soon be mounted, and for spectra of feeble luminosity a smaller spectrograph with prisms is available. The electric current for production of the voltaic arc is generated by a very fine Siemen's shunt dynamo worked by a gas engine of 4 HP. For the study of the spectra of gases the institution possesses, besides several induction coils of small and medium size, a great Ruhmkorff capable of giving, when worked by a battery of 12 large Bunsen cells, a stream of sparks of 50 cm.

After putting all these appliances in working order some time was spent in several preliminary researches, mainly in the view to test the efficiency of the apparatus. One of these re-

* Svenske Vetenskapsakademiens Handlingar, Bd. 24, No. 3, 1891.

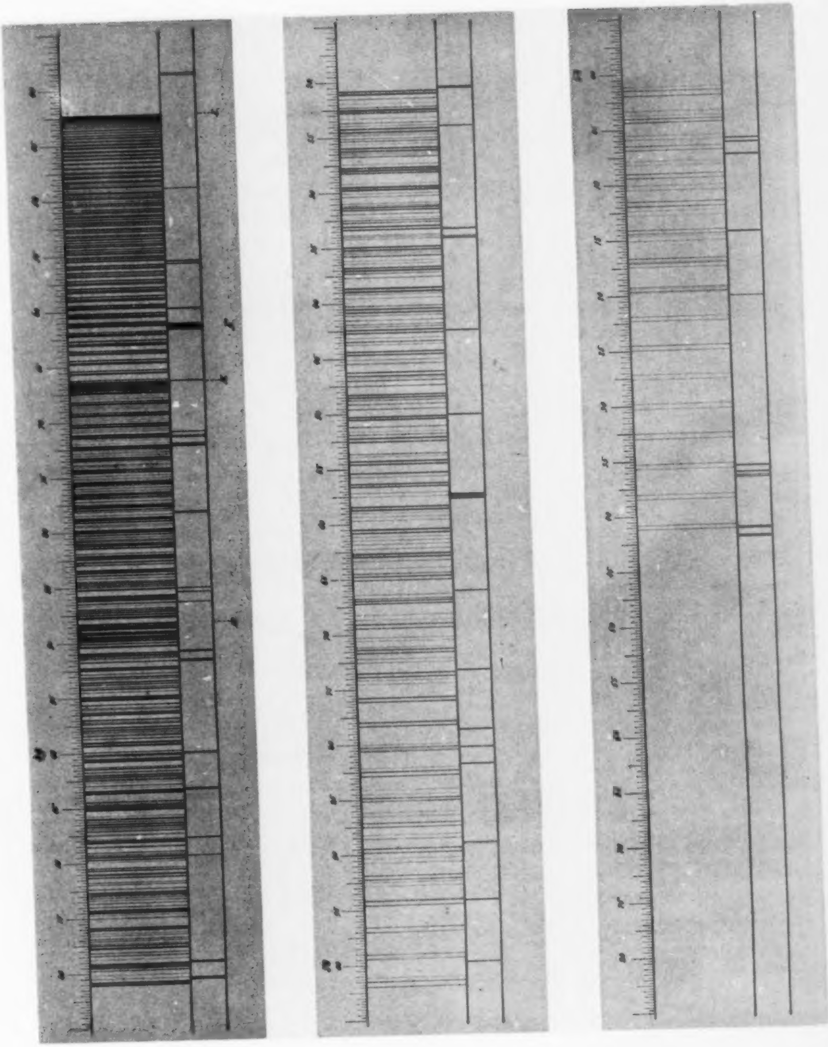
searches concerns the spectrum of aluminium oxide, which, when generated in the arc and viewed with the above-named spectroscope presents itself with a lustre and richness of detail never before observed. This circumstance induced me to make a careful investigation thereof, although the spectrum has no recognized relation to solar or sidereal physics. Perhaps a brief account of the results of this investigation* will be of interest to the readers of this journal.

As well known the spectrum of aluminium oxide consists of five groups of flutings in the yellow, green, blue and violet, each group composed of a number of smaller partial flutings of decreasing intensity in the direction of increasing wave-lengths. The first description we owe to Thalén, who, in the same manner as Lockyer and Lecoq de Boisbaudran, employed the uncondensed induction spark. Under these circumstances, the intensity being small, it is obvious that only very moderate dispersion could be used, and thus we find that all these older investigations do not give any more details than the positions of the sharp edges of the flutings. As moreover, the employment of the condensed spark in order to increase the intensity is out of the question because the temperature then surpassing that of dissociation, the spectrum of the oxide is replaced by that of the metal, it occurred to me that the electric arc, whose temperature lies between that of the uncondensed and condensed spark, would do good service, a supposition which experiment has most satisfactorily confirmed.

The whole investigation was made with the help of photography in the third order. With the great dispersion thus obtained every fluting of the spectrum was resolved into very bright separate sharp lines. The spectrum was photographed on Edward's isochromatic plates, together with the corresponding parts of the solar spectrum, thus giving the means for determining the wave-lengths of the lines by measurements on the dividing engine. For these determinations the Rowland standard lines were employed, as a thorough comparison had showed that the *relative* accuracy of this system notably exceeds that of the Potsdam catalogue. Moreover, a good many (about 50 per cent) of the Potsdam standard lines are under the great dispersion here used not single, but form groups of two, three, or sometimes four lines, in which cases any certain identification of the given positions is impossible. As to the question which of the two systems is to be considered *absolutely* more correct, nothing

* Zur Spectroskopie der Verbindungen. Spectrum der Thonerde. Svenska Vetenskapsakademiens Handlingar. Bd. 24, No. 15, 1892.

PLATE XXXIX.



The Spectrum of Aluminium Oxide as Photographed by Professor B. Hasselberg.

evidently can as yet be affirmed, but the *relative* homogeneity of the system being the main point, this is here a circumstance of subordinate weight, which perhaps only the employment of quite new methods for wave-length determination may be apt to settle.

For igniting the oxide the employment of massive bars of aluminium as electrodes in the lamp is not practicable, because the current is soon interrupted by the oxide immediately formed. Instead of this I have introduced small fragments of the metal into the crater of the lower hotter carbon electrode and thus obtained an arc of sufficient steadiness, in which the oxide was evaporated. Together with the spectrum of the oxide the plates then of course contain also a number of foreign lines mainly pertaining to iron from the carbon poles. Happily the carbons now prepared by Siemens at Berlin are very pure, and in consequence neither the number nor the strength of these lines is of any importance. On the contrary, their presence, namely that of the iron lines, is of very great use as a check on the unaltered position of the spectrograph during the time of exposure. Nothing short of such an immediate criterion can assure freedom from constant errors in relative determinations of wave-lengths of the present nature.

The results obtained are contained in a catalogue of wave-lengths of about 3,000 lines. The probable error of these values does not in general exceed $\pm$ 0.02 X-metres. Besides the lines of aluminium-oxide the catalogue contains also the standard solar lines employed, in order that every correction which these standards may need in the future can immediately be applied to the corresponding part of the catalogue. It must be understood, however, that this list of lines does not include everything visible of the spectrum, but only the most prominent features of it, as contained in the four great flutings in the green, blue and violet. The yellow fluting, which in instruments of small power is well seen, becomes here very insignificant, and therefore does not deserve more special attention than the crowd of very feeble lines which fill almost the whole extreme violet and whose determination would have unduly prolonged this preliminary inquiry.

In order to give an idea of the magnificent structure of these flutings as seen on my photographs, the memoir is accompanied by a phototypic reproduction of my drawing of the main fluting in the neighborhood of F. From the same drawing the annexed plate is also copied in reduced size.

After terminating this inquiry, the main investigations on the arc-spectra of metals were commenced. From an astro-physical point of view, the spectrum of iron is indeed of first importance.

As, however, through the investigations of Thalén and Kayser and Runge, our knowledge of this spectrum may be considered tolerably perfect, I thought it of next importance to make a similar study of chromium, nickel, cobalt and manganese, of whose spectroscopy only the outlines are as yet roughly known. In the first of these spectra, the researches of Huggins, Thalén and Lockyer give altogether only about 70 lines, whereas on my plates, about 800 have been recorded between D and λ 345. A similar proportion will also probably hold good for the other metals. With the aim to eliminate foreign lines, the spectra are also photographed by pairs on the same plate, *e. g.*, chromium and nickel, chromium and iron, and so on, thus enabling the observer to judge exactly of any coincidence, and in such cases to trace the lines in question to their most probable origin. In this way, I have found that when *exact* coincidence occurs between lines in two such spectra the origin of the lines may generally be determined without difficulty from the ratio of their intensities. In a few instances (for iron and chromium perhaps one per cent of the whole number) exact coincidence has of course been recorded also for lines of equal intensity. These lines, which generally are faint and most probably originate in impurities common to both metals or from the electrodes, are in general to be excluded. From this circumstance, and from the fact that lines whose distances exceed 0.04 or 0.05 X-metres are easily and undoubtedly separated on my plates, I think it may be safely concluded that lines really common to two or more metals most probably do not exist.

For such metals as are to be obtained only in fragments or powder, as for example, cobalt and chromium, carbon electrodes, in the crater of which the metallic fragment or powder is placed, have generally been used. For those spectrum regions, however, in which the strong carbon flutings lie, other electrodes are to be employed, because in the crowd of carbon lines the fainter metallic lines cannot be surely discerned. For this purpose, thick copper electrodes have served very well, especially in the lower ultra-violet where the copper lines are few in number and easily distinguished.

In connection with these remarks, a singular observation concerning the corona line of the Sun may be mentioned. As proved for the first time by Young this line is double, a fact easily confirmed in my spectrograph not only in the third order, where the components are widely separated, but also in the second order. Of these two lines the upper one is as yet of unknown origin, whereas the lower component has been attributed to iron. In fact, there exists in this place a very feeble iron line, but it is, I think, next to certainty that this line is only an impurity in the iron spectrum caused by the presence of cobalt. On the photographs of this region of the cobalt spectrum which I have taken in the third order the solar line in question has a strong counterpart in the spectrum of this metal. The coincidence is undoubtedly perfect, but as to the iron line I do not feel sure, because on account of its weakness I have as yet not succeeded in bringing it out on my plates. This point will shortly be more closely investigated. So much seems, however, to follow from this observation, that the solar line in question most probably is due to cobalt and not to iron.

THE SPECTRUM OF NOVA AURIGÆ IN FEBRUARY AND MARCH, 1892.*

W. W. CAMPBELL.

The announcement of the appearance of a new star in Auriga reached Mt. Hamilton the 6th of February. This paper relates to spectroscopic observations made by me on seven nights between February 8 and March 13 inclusive. On the latter date the magnitude of the star was about 7.4. During the succeeding six weeks its brightness decreased fairly uniformly until, when the last reliable visual observation was made, April 24th, it was of about the sixteenth magnitude. In this period of decline the nights available for my use were cloudy for the most part, and the few attempts to secure observations were frustrated by the fogging of the object-glass.

APPARATUS.†

The observations, both visual and photographic, were made with the large Brashear spectroscope and 36 inch equatorial. In the visual observations the 10½-inch view telescope and an eyepiece magnifying 13.3 times were used. The third and fourth orders of a grating of 14,438 lines to the inch were not found suitable for the study of this spectrum, principally on account of the strength of the continuous spectrum and the great breadth of the

* Communicated by the author.

† A portion of the apparatus used in this work was purchased by a grant of money from the Thompson fund of the Amer. Ass. Adv. Science.

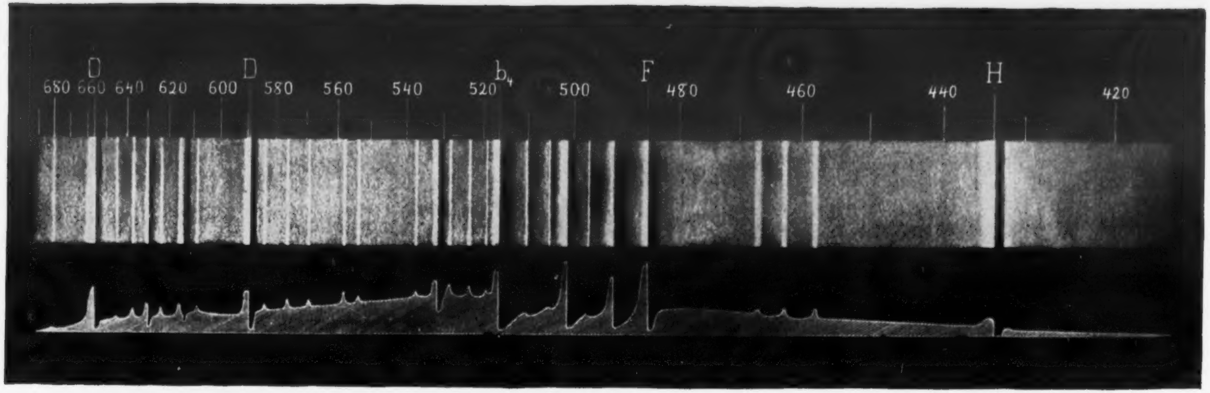
lines. The Observatory did not then possess first and second order gratings, which could probably have been used to advantage. A dense thallium compound prism, dispersing 12° between B and H, was used several evenings in fixing the positions and examining the character of the bright hydrogen lines, the D sodium lines, and a few other important lines. But an excellent 60° dense flint prism by Brashear, dispersing 5½° between B and H, was for several reasons better adapted to a general determination of the wave-lengths and was usually employed. With this prism the power of the spectroscope is such as easily to separate b_3 and b_4 in the solar spectrum, which are 1.6 tenth-metres apart.

In the photographic observations the eyepiece and micrometer were replaced by a camera box suitable for holding a small plate-holder. No other changes were required to adapt the spectroscope to photography. In the winter I had decided to apply photography to spectroscopic work here; and, fortunately, on February 5 I had fitted the camera box and determined the photographic focus. It is to be regretted that the Observatory did not then possess apparatus suitable for photographing the spectrum with greater dispersion than that given by the 60° prism.

THE VISIBLE SPECTRUM.

The general character of the visible spectrum is shown in the accompanying drawing of the spectrum and of the intensity curve; though in the former the contrast between the faint lines and the continuous spectrum was necessarily overdrawn. Many of the lines between D and F were so nearly masked by the continuous spectrum that under stronger dispersion they would have escaped detection entirely. The region between F and Hγ was seen to contain a large number of bright lines. A few of the more prominent ones were located the first evening; but two photographs taken later the same evening showed the lines in this region so satisfactorily that thereafter no effort was made to observe them visually. The drawing therefore, really refers only to the portion of the spectrum below and including the F region, and is based upon the observations of February 8, 9 and 28. The intensity curve was drawn almost wholly from sketches made February 28, when the continuous spectrum had faded slightly, unmasking many of the lines previously invisible. On March 13, the continuous spectrum had in many regions wholly disappeared, and interfered with only a few of the measurements. A line at λ 5885 observed on the latter date only is not shown in the drawing.

PLATE XL.



Visible Spectrum of Nova Aurigæ, 1892, February 28, from Observations at the Lick Observatory, by W. W. Campbell.

Altogether there were observed visually thirty bright lines, not counting a bright region at λ 432 and a faint line occasionally glimpsed near λ 680; and ten broad dark lines in contact with the more refrangible edges of ten of the strongest bright lines. Careful searches for lines below C were made, but only the trace of a line near λ 680 could be seen. In each of the ten dark lines, except that above Hγ, a background of continuous spectrum was still visible, and was so noted on several evenings. These lines were sharply defined below by the bright lines, but were diffuse above. They were from twelve to fourteen tenth-metres broad, and their centres were about eleven tenth-metres more refrangible than the most intense points in the corresponding bright lines. But the dark and bright lines evidently overlapped, and it is probable that their real centres were slightly less refrangible than their apparent centres. Possibly the real centres were near the fine bright lines shown in the photographs, which will be referred to later.

As stated in ASTRONOMY AND ASTRO-PHYSICS for March, 1892, the normal positions for the hydrogen C, F and Hγ lines and the D sodium lines were occupied by bright lines. These and the lines λ 5168 and 5016 were carefully studied to obtain very accurately their positions and light curves. On the first few evenings all these lines were examined with the compound prism and extremely narrow slit, but no evidence of doubling was obtained; though with the exception of the D lines they were certainly very far from being uniformly bright throughout their breadth. The hydrogen lines C, F and Hγ, and the lines λ 5168, λ 5016 and λ 4923 were at least fifteen tenth-metres broad. Their more refrangible edges were quite sharply terminated. From the most intense points, which were about four tenth-metres below the upper edges, the intensity decreased about as shown in the drawing of the intensity curve, finally gradually merging into the continuous spectrum. The bright D line was about fifteen tenth-metres broad, quite sharply defined above, nearly uniform in brightness for ten or twelve tenth-metres, then merging gradually (but more sharply than the others) into the continuous spectrum below. The D line had greatly decreased in brightness by February 28; on March 13 it had apparently disappeared, and a faint line more refrangible than D was observed at λ 5885. The appearance of the spectrum at this point had changed considerably.

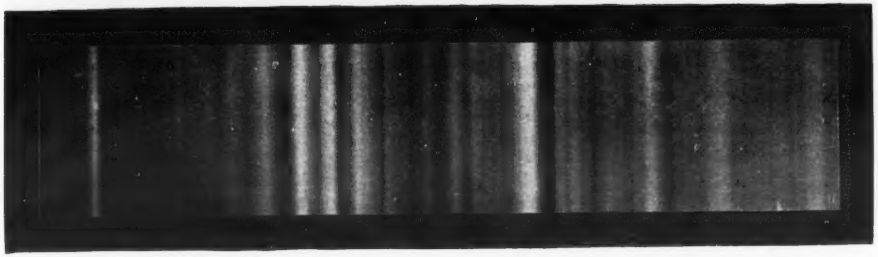
The points of maximum intensity in the C, F, and Hγ bright lines were well enough defined to permit their wave-lengths to be determined within one tenth-metre, as was found by first setting the micrometer wire on the star lines and then throwing in the hydrogen comparison spectrum. These comparisons were made on several nights, and the star lines were found to coincide with the comparison lines within the limits stated above. I therefore adopted for the wave-lengths of these lines their usual values 6563, 4862 and 4341. On three nights the D star line and the D sodium lines of the spark spectrum and of the flame were carefully compared. With the compound prism and narrow slit the comparison lines were widely separated. When the micrometer wire was placed in contact with the upper edge of the star line it was also in contact with the upper edge of D_2. The comparison line D_1 appeared to fall in the exact centre of the broad star line, and I have accordingly adopted for it the wave-length 5896. The point of maximum brightness in the line λ 5168 was not well defined; but comparisons with magnesium b_4 showed that the wave-lengths were practically equal. The regions of maximum brightness in the lines λ 5016 and λ 4923 were likewise quite broad, which made an accurate determination of their wave-lengths impossible.

Assuming the wave-lengths either of the comparison lines or of the star lines at λ 6563, λ 5896, λ 5168, λ 4862 and λ 4341, the wave-lengths of the intermediate lines were generally obtained from the readings of the large circle (12 inches in diameter, reading to 10″) corresponding to the different lines in the star, by interpolating between the assumed wave-lengths by means of curves based upon the solar spectrum. In some cases the wave-lengths could probably have been obtained more accurately by making micrometer comparisons, but usually the method employed was the most satisfactory for this spectrum. The wave-lengths resulting from the visual observations on five nights are given below. The appearance of a line depended upon its breadth, intensity and position in the continuous spectrum, and it is impracticable to give a verbal description of the lines in this place. Reference can be made to the general intensity curve.

WAVE-LENGTHS OF BRIGHT LINES OBTAINED VISUALLY.

Feb. 8	Feb. 9	Eeb. 22	Feb. 28 [680]	March 13	Means [680]
6563	6563	6563	6563	6563	6563
6447	......	......	6456	......	6451
6363	6380	......	6367	6367	6369
6294	6299	......	6296	6295	6296
6251	6236	.. ...	6234	......	6240
6151	6156	......	6158	......	6155

PLATE XLI.



F Hγ Hδ

Photographic Spectrum of Nova Aurigæ, Hγ Region, 1892, February 9.

Feb. 8	Feb. 9	Feb. 22	Feb. 28	March 13	Means
......	......	......	6087	......	6087
5896	5896	5896	5896	......	5896
......	......	......	......	5885	5885
......	......	......	5841	......	5841
......	......	......	5759	5763	5761
......	......	......	5690	......	5690
5585	5576	......	5575	5576	5578
......	......	......	5535	......	5535
5376	5372	......	5375	5390	5378
5320	5317	......	5321	5313	5318
5282	5282	......	5281	5274	5280
5229	5228	......	5237	5233	5232
5193	......	......	......	5193	5193
5167	5168	5168	5168	5168	5168
5103	5101	......	......	5103	5102
5056	......	......	......	5055	5055
5016	5013	5015	5016	5012	5014
4969	4972	......	4965	......	4969
4926	4922	......	4925	4921	4923
4862	4862	4862	4862	4862	4862
4670	......	......	......	......	4670
4629	......	......	......	......	4629
4583	4584	4582	......	......	4583
4341	4341	......	4341	4341	4341
......	......	......	[432]	......	[432]

THE PHOTOGRAPHIC SPECTRUM.

The 36-inch telescope is not suitable for a general study of the photographic portions of stellar spectra. Only a very limited region of a stellar spectrum can be photographed at one time to advantage, for the reason that the color curve of the 36-inch objective is very steep in the blue and violet, and only a few of the rays enter the slit. The focal length of the objective is 37mm. greater for the Hγ rays than for the F rays, and 34mm. greater for the Hδ than for the Hγ rays. For a given position of the spectroscope slit the rays of a certain wave-length come to a focus (a point) on the slit and pass through properly; those of greater wave-length are in focus before reaching the slit, and only a few of them pass through; those of smaller wave-length do not reach their focus and only a few of them pass through the slit. Beyond Hδ the curve is so steep as practically to prevent the taking of photographs in that region. Another serious difficulty enters in that region of the spectrum: the image formed on the slit plate by the brighter visual rays is large and interferes very greatly with keeping the point in focus in the slit.

The photographs of Nova Aurigæ's spectrum were taken in two sections and with two sets of adjustments: first, with the slit in the focus for the F rays and the prism at minimum deviation for F; second, with the slit in the focus for the Hγ rays and the prism in minimum deviation for Hγ. In the first case the F rays proceeding from all parts of the object-glass entered the slit, while of the rays of greater or less wave-length only those proceeding from a region of the object-glass along and near the diameter parallel to the slit entered the slit at all. A similar result obtained for the Hγ setting. With ordinary dry plates the F photographs extend from the slightly actinic region λ 5200 to λ 4300, and are densest near and above F; and the Hγ photographs from λ 5000 to λ 4100 and densest in the Hγ region. One successful F photograph was obtained on an isochromatic plate, on February 14, which is measurable from λ 5686 to λ 4341. It is evident that the relative photographic brightness of lines in different parts of the spectrum cannot be obtained from these plates.

With the above limitations the photographs were successful from the first, and in all seven measurable negatives were obtained. A list of them is given below:

Date.		Region.	Slit Width.	Exposure.	Remarks.
1892, Feb.	8	F	0.0020 inch	15m	
"	8	Hγ	0 0020 "	15m	
"	9	F	0.0015 "	32m	
"	9	Hγ	0.0015 "	26m	
"	14	F	0.0011 "	37m	
March	6	F	0.0010 "	120m	Very windy
"	6	Hγ	0.0010 "	150m	" "

The spectrum of hydrogen was photographed on each plate for purposes of comparison, very near the stellar spectrum; on one side of it before beginning the exposure on the star and on the other side after closing the exposure. The original negatives were measured by means of a Stackpole measuring engine, and the measures were converted into wave-lengths by the aid of photographic interpolation curves. A list of the wave-lengths of bright lines obtained from each of the plates is given below. The results are corrected for the observer's motion and for curvature of the comparison lines. In a few cases it is impossible to determine from the negatives whether the lines measured were bright lines or were strong continuous spectrum between dark lines. In order to test the adjustments of the instrument, the lunar and hydrogen spectra were frequently photographed on the same plate, likewise the solar and hydrogen spectra, with the hydrogen tube both in front of the slit and at one side, and no displacement could be observed. A photograph of the spectrum of α Orionis showed the lines to be fine and sharp, while with the same adjustments and settings those of Nova's spectrum were broad and diffuse.

WAVE-LENGTHS OF BRIGHT LINES OBSERVED PHOTOGRAPHICALLY.

Feb. 8. F	Feb. 8. Hγ	Feb. 9. F	Feb. 9. Hγ	Feb. 14. F	Mar. 6. F	Mar. 6. Hγ	Means.	Remarks.
…	…	…	…	5685	…	…	5685	Maximum in broad line.
…	…	…	…	5630	…	…	5630	Maximum in broad line, poorly defined.
…	…	…	…	5584	…	…	5584 }	Two prominent lines, clearly separated.
…	…	…	…	5575	…	…	5575 }	
…	…	…	…	5534	…	…	5534	Maximum in broad line.
…	…	…	…	5454	…	…	5454	Maximum in broad line.
…	…	…	…	5379	…	…	5379	Maximum in broad line.
…	…	…	…	5329	…	…	5329 }	Double line very similar to F line.
…	…	…	…	5318	…	…	5318 }	
…	…	…	…	5285	…	…	5285 }	Prominent line, probably double, but not clearly separated.
…	…	…	…	5276	…	…	5276 }	
…	…	…	…	5234	…	…	5234	Very faint, poor.
…	…	…	…	5200	…	…	5200	Very faint, poor.
…	…	…	…	5176	…	…	5176 }	Similar to F line, double, but not clearly.
…	…	5170	…	5168	5170	…	5169 }	
…	…	…	…	5159	…	…	5159	Very faint companion to above.
…	…	…	…	5142	…	…	5142	Very faint line.
…	…	…	…	5095	…	…	5095	Faint line, poor.
5017	…	5019	…	5018	5018	…	5018	Similar to F line, no signs of doubling.
…	…	trace	…	5007	trace	…	5007	Companion to above.
4969	…	trace	…	4969	4969	…	4969	Faint, poorly defined.
…	…	…	…	…	4929.1	…	4929	Well defined March 6, equal to line below.
4922	…	4923	4923	4922.9	4921.7	4923	4923	Maximum of line resembling F line.
trace	…	trace	…	4913.2	4913.0	…	4913	Companion to above.
…	4871.3	…	4871.2	4868.9	4868.2	…	4869.9	Well defined March 6.
4861.7	4862.2	4861.4	4861.8	4861.1	4860.8	4862	4861.6	Principal F line.
4851.6	…	4851.8	4851.6	4852.0	4849.1	…	4851.2	Companion to above.
4777	…	4772	…	4773	…	…	4774	Estimated centre of very broad bright region.
4733	…	4739	…	4739	…	…	4737	Estimated centre of very broad bright region.
4700	…	4703	4715	4709	…	4710	4707	Estimated center of broad bright region.
4671	…	4666	4672	4669	…	4668	4669	Centre of broad bright line.
4628	4632	4628	4631	4630	4631	4630	4630	Centre of broad bright line.
4588	4588	4587	4586	4587	4581	4585	4586	Centre of broad bright line.
4575	…	4576	4576	…	…	…	4576 }	Either well defined bright lines or continuous spectrum between absorption lines.
4570	…	4570	…	…	…	…	4570 }	
…	…	4564	4565	4564	…	…	4564 }	A group of lines, defined on fourth and fifth negatives, blended on the others.
4556	…	to	4559	…	…	4561		
to	4553		4554	4556	4554	to	4554 }	
4546	…	4547	4549	4549	…	4545	…	
4533	4533	4538	4524	4538	…	4528	…	
to	to	to	to	to	4516	to	4518	Appears like a group of lines, but not well defined.
4504	4504	4500	4509	4511	…	4504	…	
4490	…	4493	4494	…	…	4496	…	A group of lines not well separated, with maximum about λ4481.
4483	…	to	to	4479	4480	to	4481	
4469	…	4478	4470	…	…	4469	…	
…	…	4455	…	…	…	…	…	
4446	…	to	4445	4444	…	4446	4445	A group of lines with maximum about λ4445.
…	…	4441	…	…	…	…	…	
…	…	4436	4437	…	…	…	4436	Broad bright line.
4421	…	4420	4418	4418	…	4420	4419	Maximum of broad line.
4383	…	…	4386	…	…	4387	4385	Centre of bright region, apparently containing several lines.
…	…	4374	…	…	…	4376	4375	Rather broad line.
…	…	…	…	…	…	4355	4355	Apparently a third component of Hγ line.
…	4347.9	4348.0	4348.9	4347.9	…	4346.2	4347.8	Component of Hγ line, usually well defined.
4340.8	4340.2	4340.7	4341.5	4340.6	…	4340.1	4340.6	Principal Hγ line.
4332.1	4332.2	trace	4331.5	trace	…	4329.4	4331.3	Companion to above.
…	…	…	4316	…	…	…	4316	Broad, appears double.
…	4296	…	4297	…	…	…	4296	Broad, well defined.
…	4266	…	4269	…	…	…	4267	Centre of broad line.
…	…	…	4246	…	…	…	4246	Broad diffuse line.
…	4238	…	4234	…	…	…	4236	Broad bright line, resembles F and Hγ groups.

WAVE-LENGTHS OF BRIGHT LINES.—*Continued.*

Feb. 8. F	Feb. 8. Hγ	Feb. 9. F	Feb. 9. Hγ	Feb. 14 F	Mar. 6 F	Mar. 6 Hγ	Means.	Remarks.
....	....	....	4227	....	....	....	4227	Faint companion to above.
....	....	....	4209	....	....	....	4209	Broad diffuse line.
....	....	....	4180	....	....	....	4180	Very bright line.
....	....	....	4166	....	....	....	4166	Broad defined line.
....	....	....	4126	....	....	....	4126	Broad defined line.
....	....	....	4108	....	....	....	4108	Component of Hδ.
....	....	....	4102	....	....	....	4102	Principal Hδ line.
....	....	....	4095	....	....	....	4095	Companion to Hδ.
....	....	....	4082	....	....	....	4082	Maximum of broad line.

An enlargement of the Hγ photograph of February 9 is shown in Plate XLI. A few defects in the original negative, mostly in the region of F, have been made to appear as lines by the cylindrical lens used in enlarging.

IDENTIFICATION OF THE LINES.

It was early noted by Professor Vogel and others that the half dozen prominent lines in Nova's spectrum coincided with prominent lines in the spectrum of the solar chromosphere. The probability that any line would be observed is a function of its intensity and the frequency with which it occurs, and therefore of the product of these two quantities. In the following table I have arranged a list of chromosphere lines whose wave-lengths agree closely with those of the lines in Nova's spectrum, placing opposite them the name of the element from which they originate, and the product F × I of their frequency and intensity. They are selected from Professor Young's catalogue of 273 chromosphere lines, as given in Scheiner's *Spectralanalyse.* A few of the identifications are doubtful and are enclosed in brackets [ ]. The faint and infrequent chromosphere lines are not inserted in the list. It appears that nearly all the prominent lines in Nova Aurigae's spectrum are prominent lines in the chromosphere spectrum, and *vice versa.* In the last two columns of the table are given a few other probable identifications. Many of the lines left unidentified fall near prominent lines or groups of lines in the spectrum of iron; while practically all of the lines can be matched by lines in the spectra of those elements which are prominent in the chromosphere. As surmised by Professor Young, ASTRONOMY and ASTRO-PHYSICS for April, the lines λ 6296 and λ 5578 are near the auroral lines λ 6298 and λ 5571. Likewise, the lines λ 5378, λ 5232, λ 5196, λ 4630 and λ 4355 are near other auroral lines; but the presence of so many iron lines in the spectrum renders it probable that these also are iron lines.

Nova Aurigæ.		Chromosphere Lines.			Other Lines.	
Visual	Photographic	λ	F x I	Element	λ	Element
[680]	......	......	......	......	......	......
6563	......	6563	10000	Hydrogen	......	......
6451	......	[6455]	60	——	6451	Calcium
6369	......	......	......	......	......	......
6296	......	......	......	......	6303.98	Iron
6240	......	[6247]	40	Iron	......	......
6155	......	......	......	......	6161.55	Sodium
6087	......	......	......	......	......	......
		{5896}	1500	Sodium	......	......
5896	......	{5890}	1500	Sodium	......	......
5885	......	[5876]	9000	Helium	......	......
5841	......	......	......	......	......	......
5761	......	......	......	......	......	......
5690	5685	......	......	......	5688.83	Sodium
......	5630	......	......	......	......	......
5578	{5584}	......	......	......	5587	Iron
	{5575}	......	......	......	5576.70	Iron
5535	5535	5535	600	Iron	......	......
......	5454	5456.47	80	Iron	......	......
5378	5379	[5372]	30	Iron	......	......
	{5329}	5317	4500	Iron, Cor.	......	......
5318	{5318}	5317	4500	Iron, Cor.	......	......
5280	{5285}	5285	200	Iron	......	.. ...
	{5276}	5276	450	Iron	......	......
5232	5234	5235	80	Iron, Mn.	......	......
5193	5200	5198	150	. ....	......	......
	{5176}	5184.72	3250	Magnesium	......	......
5168	{5169}	5169.68	1800	Iron, Mg.	......	......
	{5159}			......	......	......
......	5142	. ...	......	......	......	......
5102	5095	......	......	......	......	......
5055	trace	......	......	......	......	......
5014	{5018}	{5019}	450	Iron	......	... ..
	{5007}	{5016}	300	Titanium	......	......
				......	......	......
4969	4969	......		......	......	......
				......	......	......
	{4929}	4924	480	Iron	......	......
4923	{4923}	......	......	....	......	......
	{4913}	4919	60	Iron	......	......
				......	......	......
	{4869.9}			......	......	......
4862	{4861.6}	4861.6	8000	Hydrogen	......	......
	{4851.2}			......	......	......
......	4774	......	......	......	......	......
......	4737	......	......	......	......	......
......	4707	......	......	.. ...	4705	Magnesium
4670	4669	......	......	......	4669.65	Sodium
4629	4630	4630	270	Iron	4629	Cerium
4583	4586	4584	90	Iron	......	......
......	4576	......	......	......	[4573]	Cerium
......	......	......	......	......	[4572]	Titanium
......	4570	......	.... .	......	[4571]	Magnesium
.. ...	4564	4566	30	Iron	......	......
......	......	4564	50	Titanium	......	......
......	4559	4560	16	Iron	......	......
......	......	4556	50	Iron	......	......

Nova Aurigæ.		Chromosphere Lines.			Other Lines.	
Visual	Photographic	λ	F x I	Element	λ	Element
......	4554	4554	50	Barium	......	......
......	4549	4550	80	Iron	......	......
......	4534	4534	25	Iron	......	......
......	to			......	......	......
......	4502	4502	90	Titanium	......	......
......	4490	4492	160	Manganese	......	......
......		4490	45	Iron	......	......
......	4481	4482	10	Iron	4481	Magnesium
......		4472	2500	Cerium	......	......
......	4471	4470	100	Iron	......	......
......	4445	4444	20	Iron	......	......
......	4436	......	......	......	4435	Calcium
......	4419	......	......	......	......	......
......	4385	4385	16	Ca., Ce.	......	......
......	4375	4376.75	39	Iron	......	......
......	4355	......	......	......	4354	Calcium
	4347.8			......	......	......
4341	4340.6	4340.7	6500	Hydrogen	......	......
	4331.3			......	......	......
[432]	4316	......	......	......	4318	Calcium
......	4296	......	......	......	......	.....
......	4267	......	......	......	......	......
......	4246	4246	90	Iron	......	......
......	4236	4236	150	Iron	......	......
......	4227			......	[4227]	Calcium
......	4209	[4216]	180	Calcium	.....	......
......	4180	......	......	......	......	......
......	4166	......	......	......	4167	Magnesium
......	4126	......	......	......	......	......
......	4108			......	......	......
......	4102	4102	5000	Hydrogen	......	......
......	4095			.....	......	......
......	4082	4078	50	Calcium	......	......

Near the centres of all the broad absorption lines shown on the photographs were comparatively fine bright lines. They were measurable at λ 5159, λ 5007, λ 4913, λ 4851 and λ 4331. They probably existed also at λ 6552, λ 6285, λ 5885 and λ 5307, since it was noted that the continuous spectrum showed faintly in the emission lines at those places, which effect was probably due more to the presence of the fine lines than to the very much fainter continuous spectrum shown in a few of the photographs.

If they existed on the more refrangible sides of other prominent bright lines they were either concealed by the strong continuous spectrum, or, in certain regions, confused with other lines. We can probably say they existed in all the broad absorption lines, but we cannot say whether or not they existed quite independently of the absorption lines.

CONCLUSIONS.

It has generally been conceded that Nova Aurigæ was a system of at least two bodies, one giving rise to the system of very bright lines, the other to the system of broad absorption lines. On several photographs a very faint continuous spectrum showed as a background in the absorption lines. This probably belonged to the bright line spectrum or spectra. The strong continuous spectrum which masked many of the fainter bright lines probably belonged to the dark line spectrum. Nearly all the photographs show the F and Hγ bright lines to be double, with different degrees of clearness. There are signs of doubling in the strong lines in the green, and on the F negative of March 6, the line λ 4923 is distinctly separated into two nearly equal components.

Professor Vogel has accounted for the observed phenomena in this manner: the fine bright lines within the broad absorption lines were due to reversals such as are sometimes observed in the spectra of Sun-spots, and were caused by eruptions of gases from the interior of the body furnishing the dark line spectrum; the doubling of the bright lines was due to the presence of two bodies possessing bright line spectra; and therefore Nova was a system of three bodies moving with very different velocities in the line of sight.

Dr. and Mrs. Huggins have suggested a further simplification, and have ingeniously explained the apparent doubling and great breadth of the bright lines by combining the reversion theory of Zöllner and Vogel with the tidal theory of Klinkerfues and Wilsing. They consider Nova as a system of two bodies, one yielding a bright line spectrum and the other a dark line spectrum.*

The reappearance of Nova as a planetary nebula, apparently with only one system of lines, favors a simple origin. But the fact that the present system of lines does not coincide with any one of the four former systems either makes the original spectrum more complex, or it shows conclusively that orbital motion has ensued. In the latter case much light must be thrown upon the question by continued observation of Nova's velocity, and considerable time may be required.

While the hypothesis of two bodies quite generally satisfies the observations and has the further very great advantage of simplicity, there are a few not unimportant points furnished by the

* See ASTRONOMY AND ASTRO-PHYSICS for August, 1892.

photographs which favor the existence of three or four bodies: two or three yielding bright line spectra and one a dark line spectrum. These points are:

First.—The two components of the bright lines are much more clearly defined in the later photographs than in the earlier. This was partly but not wholly due to the decline of the continuous spectrum. The photographs taken earlier in February show the broad bright lines F and λ 4923 to be double only with difficulty. Two condensations, the more refrangible one being the stronger, show certainly, but not clearly. The F photograph of March 6 shows these lines as well defined doubles. In the line λ 4923 the two components are separated too widely to present the appearance of reversion, and the continuous spectrum shows only very thinly in that region.

Second.—In all the double lines shown on the March 6th photographs the two components are nearly equal, while in the earlier photographs the more refrangible components were the stronger.

Third.—There is some reason to believe that the intervals between the components were less in March than in February, though on the earlier negatives the measures were subject to considerable uncertainty, and photographs taken elsewhere do not seem to show this variation.

Fourth.—The normal position of the fainter lines throughout the spectrum (as compared with the chromosphere spectrum) is evidence that they were mostly associated with the more refrangible components of the double lines, *and not with the double lines as a whole*.

Fifth—The fine bright lines appeared not only in the dark F and $H\gamma$ lines, but also in three dark lines in the green, all apparently in the same position relative to the principal series of bright lines.

Sixth—During the decline of Nova in brightness the continuous spectrum belonging mostly to the dark line star decreased more rapidly than the bright lines, while the fine bright lines decreased certainly no more rapidly than the principal bright lines.

The above evidence is far from conclusive, and is inserted now merely for completeness. On the hypothesis of four bodies, the principal system of bright lines was not displaced appreciably, and the star yielding it was practically at rest with reference to the solar system. Another system was displaced towards the red a distance corresponding to a velocity of recession of about 315 miles per second. The system of fine bright lines and likewise the system of dark lines were displaced towards the violet a distance corresponding to a velocity of approach of about 400 miles per second.

The relation of the early spectrum of Nova to its present spectrum was considered by me in the October number of ASTRONOMY AND ASTRO-PHYSICS. A careful re-examination of the negatives has revealed none of the present lines, though it is possible that the F plate of February 9 would have recorded the line now at λ 5002 had it then existed.

While it is possible for an observer to work alone in making spectroscopic observations with the great telescope, it is far from convenient and involves a serious loss of observing time. As no other person was available Professor Holden kindly volunteered to assist me in the spectroscopic observations until some other arrangement could be made. I wish here to acknowledge this efficient assistance, without which the foregoing observations would have been much more incomplete.

MT. HAMILTON, 1892, Sept. 30.

SOME RESULTS AND CONCLUSIONS DERIVED FROM A PHOTOGRAPHIC STUDY OF THE SUN.*

GEORGE E. HALE.

In view of the fact that the study of prominence, facula and Sun-spot spectra by photographic means has now been taken up by several investigators, it seems desirable to bring together the results of the work in this direction which has been in progress at the Kenwood Observatory since April, 1891. Some of these results have been published before or casually referred to in papers on other branches of solar work, but they cannot fail to be of greater value for comparison with the investigations of others if grouped in a single article. There also remain to be mentioned several disconnected matters to which attention has not yet been called.

The following are some of the results, with several conclusions to which I have been led; further investigations may very possibly render necessary material modifications in the views here expressed.

* Communicated by the author.

CHROMOSPHERE AND PROMINENCES.

1. H and K are always present as the strongest lines in the chromosphere and prominence spectrum.

2. These lines extend to the highest parts of all prominences, but have not yet been traced to any greater distance from the limb, *i. e.*, into the corona.

3. K seems to be invariably stronger than H, and extends farther from the limb.

4. In cases of motion in the line of sight the distorted forms of the H and K lines are similar.

5. Prominences have the same form in both lines. Where apparent differences exist they may probably be ascribed to the greater brightness of K. (This remark also applies to 4).

6. Both H and K expand rapidly in width from the upper surface of the chromosphere to its base. Consequently photographs taken with the slit just tangent to the limb show these lines more than twice as broad as they appear in the higher regions of prominences.

7. Both lines are often doubly reversed (narrow dark lines running down the center of the bright lines) in the chromosphere, and sometimes in the base of bright prominences.

8. H is always accompanied by a hydrogen line ($H\varepsilon$), but this line is much fainter, and does not extend so high in prominences.

9. The entire series of ultra-violet hydrogen lines have been photographed in very bright prominences, but in faint prominences the lines more refrangible than α_1 or β_1 are usually absent from the photographs. They may, however, be present as very faint lines in all prominences, but remain invisible on the photographs on account of the brilliancy of the atmospheric spectrum.

10. The line α_1 is frequently accompanied by a line slightly more refrangible, which is probably not due to hydrogen. In a few cases α_1 has been single in certain parts of a prominence, and double in other parts.

11. The upper component of α_1 is sometimes doubly reversed in the chromosphere.

12. No prominence has yet been found which showed the H and K lines alone, *i. e.*, without some of the less refrangible hydrogen lines.

13. The forms of prominences as observed in C and in H and K seem to be the same, though they may be more extensive in the latter lines.

14. Prominences seem to have the same motion in the line of sight, whether observed in C or in H and K.*

15. The spectra of eruptive prominences frequently contain many metallic lines in the ultra-violet; notably the magnesium triplet at λ 383.†

16. Eruptive prominences sometimes exhibit a continuous spectrum in the ultra-violet.

17. Prominences frequently show evidences of spiral motion.

FACULÆ.

18. Both H and K are always reversed in faculæ.

19. These reversals are usually (if not invariably) double, a narrow dark line running down the center of the broader bright line. The appearance on the photograph is consequently as if there were two narrow bright lines separated by a narrow dark line, in the centers of the broad dark shades at H and K. In some instances I have noticed that one of these narrow bright lines was missing in certain portions of a facula, an unsymmetrical double reversal resulting.

20. Distortions in the doubly reversed H and K lines of the faculæ are rare. I have found but one or two instances of this kind, and in these cases the distortions took the form of expansions in the lines.

21. H is usually unaccompanied by the slightly less refrangible hydrogen line, referred to above as being always present in prominences. In a few cases, however, this line has been found extending across spots, and for some distance in the faculæ on either side.

22. Neither α_1 nor any other bright lines more refrangible than H and K, have been found in faculæ or spots.

23. Curved forms predominate in faculæ, and suggest some relation with spiral forms in prominences.

SPOTS.

24. The bright H and K lines seem to invariably extend entirely across every Sun-spot. Both lines are doubly reversed in the faculæ which probably completely surround every spot. In the umbra the reversals are narrower, and the dark central line is usually absent.

* In one case where the motion of the entire prominence was considerable, a large number of lines in the ultra-violet (all that were visible on the photograph) were equally displaced with H and K.

† See my article on "The Ultra-Violet Spectrum of the Solar Prominences" in this number of ASTRONOMY AND ASTRO-PHYSICS.

25. Small spots, especially when members of a group containing large spots, are frequently completely covered with faculæ.

26. In the ultra-violet spectra of spots the dark lines of the solar spectrum do not seem to undergo selective widening, as in the less refrangible parts of the spectrum. Beyond the presence of the bright H and K lines, and the infrequent appearance of Hε, the spot spectrum seems to differ from the ordinary solar spectrum only by the increased general absorption.

27. Distorsions of the bright H and K lines in spots are extremely rare.

CONCLUSIONS.

28. The exact agreement of H and K with the two strongest lines in the spectrum of the calcium spark leads me to attribute these prominence lines to calcium. While the properties of calcium in its terrestrial condition make it difficult to see how its vapor can form the most important constituent of the prominences, yet I do not see how we are to escape from this conclusion.

29. No other than a negative conclusion can as yet be offered in regard to the perplexing question of the so-called "white prominences." At the eclipse of August 29, 1886, a large prominence was photographed which was said by Professor W. H. Pickering to have no other lines in its spectrum than H and K, and a faint trace of an ultra-violet line, in addition to a bright continuous spectrum. He goes on to add:* "It was therefore quite invisible, both before and after totality, by the usual spectroscopic method, as was in fact noted at the time by Professor Tacchini." The character of the photograph, at least so far as can be judged from the reproduction accompanying the report, was hardly such as to warrant any very positive statement as to the absence of the hydrogen lines, particularly as they might have been partly obscured by the bright continuous spectrum. The prominence might also have been eruptive in nature, not lasting longer than the duration of totality, and thus may not have existed when Professor Tacchini made his observations before and after the eclipse. However this may be, for this is only one of a number of cases in which "white prominences" have been recorded, I have as yet found no prominences which exhibited H and K without the hydrogen lines. This point has not been made the subject of special investigation, however, and it

* Annals of Harvard College Observatory, Vol. XVIII, No. 5, p. 100.

may be that some cases of the kind may ultimately be brought to light.

30. The fact that small spots are sometimes completely covered with faculous matter (or possibly with prominences) may assist in explaining the anomalous heat radiations recently measured in certain spots by Professor Frost.* I hope to take up this point more in detail elsewhere.

31. Photographic methods have abundantly substantiated the conclusions long ago drawn from visual observations in regard to the nature of faculæ. In a great many photographs taken with the spectroheliograph, faculæ are shown projecting above the Sun's limb. And the intimate relationship between faculæ and eruptive prominences is not less evident, especially in composite photographs showing faculæ and prominences on the same plate. When we consider that eruptive prominences probably rise from faculæ, it is not at all surprising that such prominences sometimes show a continuous spectrum in addition to their bright lines. For a violent eruption would naturally carry up with the prominence some "dust-like"† matter from the facula, which would give a continuous spectrum.

32. The reversals of the H and K lines over spots seem to be readily explainable. As has been stated above, the reversals are double in the penumbra, and also for a considerable distance on either side of the spot, but usually single in the umbra. As spots seem to be always surrounded by faculæ, which frequently encroach upon the penumbra, the double reversals occur in these just as they do in faculæ not in the vicinity of spots. The single reversals in the umbra, however, probably take their rise in the chromosphere, which presumably overlies the cooler regions of the spot.

KENWOOD OBSERVATORY, University of Chicago,
Oct. 18, 1892.

THE SOLAR DISTURBANCE OF JULY, 1892.‡

JOHN S. TOWNSEND.

In his paper on "A remarkable solar disturbance," (ASTRONOMY AND ASTRO-PHYSICS, Aug. 1892), Professor Hale calls attention to an outburst similar to that witnessed by Carrington and

* ASTRONOMY AND ASTRO-PHYSICS, October, 1892.

† See Fényi, ASTRONOMY AND ASTRO-PHYSICS, May, 1892, p. 431.

‡ Communicated by the author.

Hodgson in 1859, which occurred in the neighborhood of a spot of high southern latitude which entered on the Sun's disk on July 8th. In this connection the following observations of the spot, made by me at my Observatory of Sevenoaks may not be without interest.

The instruments employed were a refractor of 4½-inches aperture and a Rowland grating spectroscope of 14,438 lines to the inch. The spot was first detected as a few small dots on June 13th. These dots rapidly developed into a spot of large area. On June 17th and again on June 20th the C line over the spot was both reversed and displaced. The spot appeared again on the E. limb on July 8th, and on both this and the succeeding date the spot and the surrounding faculæ showed strong reversals over the C line. The slit of the spectroscope was adjusted E. and W. over the spot. The position was determined by using the grating as a white light reflector and viewing the spot through the open jaws of the slit. The movable jaw was then closed, and the grating turned to give the order of spectrum required. This method permits the position of the slit relatively to a Sun-spot under observation to be determined with great accuracy.

On July 11th the spot was again examined with the spectroscope, and was found at 11:45 A. M., G. M. T., to be greatly agitated. The C line was so strongly reversed over the two most southern nuclei, that the slit could be opened to the full width of the nuclei without passing beyond the reversed position, the whole of the enclosed area glowing with flame. I have lately examined over one hundred spots with the spectroscope for reversals of the C line, and none of these, not even the great spot of Feb. 1892, showed such strong bright reversals as did this spot. The appearance was very like that observed by Professor Young in the F line over a prominence on August 3, 1872, and pictured at p. 210 of his work "The Sun." Nor were the reversals of C confined to the nuclei, for the line was also strongly reversed in the penumbra preceding the nuclei. Over the nuclei reversals were also observed in the lines D_1 D_2 D_3 b_1 b_2 b_3 b_4 F G′, and in the line λ 6676.9 of Rowland's maps. The three lines D and the *b* lines were brighter than I have ever observed them even in prominences; F and G′ showed out sharply, while λ 6676.9 was plainly reversed both in the 2d and 3rd order spectrum. Over the pennmbra D_3 appeared as a shaded line, long and spindle-shaped. At 12:30 P. M. the disturbances began to subside, the four *b* lines appearing as widened though not reversed, although C and F still continued to be reversed. At 1:30 P. M. C only was affected, being reversed over the nuclei, and distorted alongside of its reversed portion towards the red end of the spectrum. At 4 P. M. the storm had quite ceased. On July 18th the spot was examined with the spectroscope for the last time, and the C line was both reversed and displaced over the spot, although only to a moderate extent.

SEVENOAKS, ENGLAND, Sept. 9, 1892.

THE SOLAR DISTURBANCES OF JULY, 1892, AND THE ACCOMPANYING MAGNETIC STORMS.*

WALTER SIDGREAVES.

The remarkable outbursts witnessed by Professor Hale and Mr. Townsend in the spot which effected its second passage across the solar disc in the middle of last July, has led to an examination of the Stonyhurst observations of the Sun, and of the photographic records of the magnets in order to trace the life history of the spot, and to detect any possible connection of such magnetic storms as occurred during its life, with the more than ordinary outbursts recorded in this spot.

The spot was first drawn at Stonyhurst on June 14, and presented the appearance of a few dots in S. latitude 32°, and heliographic longitude 45.75°. On June 21 the spot was near the W. limb of the Sun, and had now developed into a large single spot or cluster of nuclei, surrounded by a ring of brilliant faculae. On this date also the spectroscopic examination of the Sun's limb showed a band of prominences of moderate height but extending over about 12° of arc immediately in advance of the spot. On July 8th the spot was again drawn as it reappeared at the E. limb. It was preceded by extensive faculae, and was itself still surrounded by a ring of brighter faculae. Its general appearance was very similar to that it presented when leaving the W. limb on June 21. As its area was then increasing it must have attained its maximum when on the invisible side of the Sun. The appearance was still not very much altered on July 11, the date of the outburst recorded by Mr. Townsend. On July 15, although the Sunspots were drawn at about the very time Professor Hale witnessed the phenomena he has described, a thick haze unfortunately prevented more than the mere outline of the spot being drawn. Our last record of the spot during the sec-

* Communicated by the author.

ond rotation was obtained on July 18, when it was near the W. limb. On Aug. 4 the place of the spot was occupied by a bright cluster of faculae. It is noteworthy that a second spot made its appearance and was drawn on Aug. 9th in the same latitude, but following by about thirteen degrees in longitude.

The magnets had been perfectly quiet from June 11, until at about 3 P. M., G. M. T., on the 16th, a slight disturbance commenced in the horizontal force magnet. This continued, and later appeared in all three elements as a series of small intermittent oscillations which lasted until the morning of the 18th. The spot which was forming would have been on the central meridian about the 16th. The series of small oscillations in the magnets again recommenced on the 21st, and continued until the morning of the 26th. The spot passed across the W. limb of the Sun between the 21st and 22nd. During the 26th the magnets were perfectly quiet, until quite suddenly at about 5 A. M. on the morning of the 27th, a considerable disturbance commenced in the horizontal force and declination magnets. The greatest oscillation in all three elements occurred at about 4 P. M. on the 27th, the declination magnet moving West through 24′.81. The extreme range of this magnet during the disturbance was 49′.07 The movement in the vertical force magnet at 4 P. M. on the 27th was very marked. The storm ended at about midnight of the 28th. The spot would at this date have been nearly central on the invisible hemisphere of the Sun, and judging from its appearance at the second rotation, would likewise have been of considerable area. On the visible hemisphere of the Sun nothing of any importance was to be seen. The magnets now remained generally quiet with the exception of some slight movements, the more noticeable taking place at early morning and at midnight of July 10th.

The spot had reappeared on the Sun's visible disk on July 8th. On the 11th, the day Mr. Townsend observed the remarkable reversals of the C line over the spot at about 12-15 P. M., G. M. T., a single sharp upward movement both on the declination and horizontal force magnets alone interrupted their otherwise quiescent state. In a very similar outburst observed by Professor Young over a spot on Aug. 5, 1872, (The Sun, p. 158), a shivering of the otherwise quiet magnet coincided in time with the solar storm. On the afternoon of July 12th, the magnets again began to be more violently disturbed, the storm continuing over the 13th until the morning of the 14th. The spot crossed the central meridian about the 14th. On the 15th, at the actual time when Professor Hale witnessed the remarkable phenomenon similar to that observed in 1859 by Carrington and Hodgson, there was not the slightest disturbance on the vertical force and declination magnets. There was, however, a slight trembling in the horizontal force magnet which was the prelude to the violent storm which set in and lasted over the 16th until midnight of the 17th. On the morning of the 16th unfortunately the horizontal force magnet was dismounted in order to lessen its sensibility, which had been found to be too great, but judging from the trace of the declination magnet, this storm must have been the most violent of the series. The extreme range of the swing of this magnet at 7 P. M., G. M. T., on July 16th was $1^{\circ}\ 34.73'$. After this storm the quiet was only disturbed by a few sharp movements of the magnets on the mornings of the 21st and the 22nd, until in the early hours of the 26th a disturbance set in which consisted mainly of a series of moderate oscillations, which passed away on the 29th at midnight. At this time the spot would have been about central on the other side of the Sun. On Aug. 4th bright faculæ alone reappeared in the place of the spot.

With regard to the storm of July 16 and 17, two groups of spots which appeared at the Sun's E. limb on July 4 were in transit across the disc and were each of considerably larger area than the spot in question. But on collating the magnetic curves with these spots they do not seem to be connected with the disturbances. On July 16 they were far past the central meridian, and moreover there was no storm to correspond with them as they advanced across the Sun's disc. Again at the time of the storm July 26-29, several large spots had just entered on the disc.

But that three magnetic storms should have coincided with three separate meridian passages of the same spot, and that the outburst witnessed by Mr. Townsend should have been marked by a simultaneous tremor in the magnets, while the more extraordinary phenomenon observed by Professor Hale should have been followed in a few hours by a violent storm, would seem to point to more than merely accidental coincidences, and to stamp this spot of July, 1892, as exercising a special magnetic influence. If this is so, it only serves to confirm the opinion expressed in the Stonyhurst College Observatory Report for 1883 "that there is some evidence to show that the auroræ and magnetic storms synchronize rather with particular classes of spots than with solar disturbances generally."

STONYHURST COLLEGE OBSERVATORY,
Lancashire, England, Sept., 1892.

RECENT OBSERVATIONS OF NOVA AURIGÆ, (SEPT. 8 TO OCT. 13, 1892).*

W. W. CAMPBELL.

Unfavorable weather has made it impossible to obtain many observations of Nova's spectrum in the last month. However, the position of the chief nebular line has been measured on three mornings, and the following wave-lengths and probable errors obtained:

	Sept. 15, 16^h	Sept. 22, 16^h	Oct. 12, 16^h
Compound prism†	....	5002.34 ± 0.12	....
Grating, 1st order	5002.54 ± 0.19	5002.39 ± 0.23	5003.67 ± 0.26
Grating, 2d order	5002.05 ± 0.18	5002.70 ± 0.15	5003.57 ± 0.13
Means	5002.29	5002.48	5003.62

These measures make it certain that the velocity of approach is not increasing at present, and seem to show that it is now decreasing. The observations in August and the early part of September seemed to show an increase. Such results are not opposed to the theory of orbital motion; though as stated in my paper of Sept. 8 (ASTRONOMY AND ASTRO-PHYSICS for October), the difficulties in the way of deciding the question arise not from the faintness of the lines, but from their great breadth, and further observations must be awaited. However, it seems to me that the measured increase of wave-length, 1.6 tenth metres, is a real variation.

The line in Nova's spectrum at λ 4359 is by far the brightest line shown in the photographs, and is about ten times as intense as the faint Hλ line. This line exists in the three other nebulæ which I have thus far examined for it. In Σ 6 its wave-length obtained from two negatives is 4363, and its intensity is about one-tenth that of the Hγ line. In N. G. C. 7027 its wave-length from two negatives is 4363 and its intensity is about one-fourth that of Hγ. In a photograph of the spectrum of the Orion Nebula (showing about 25 lines between λ 5007 and λ 3800) this line is shown at λ 4364, and its intensity is about one-twentieth of that of Hγ. Two negatives of the spectrum of Σ 6 show a line at about λ 4636. This undoubtedly corresponds to the line in Nova's spectrum at λ 4630. Thus both lines referred to at the close of my former paper are shown to be nebular and are properly displaced.

* Communicated by the author.

† The dispersion with the dense compound prism is slightly greater than with the grating in the first order.

A recent photograph of Nova's spectrum shows not only all the lines on the September photographs, but also three additional ones at λ 471, λ 460 and λ 451. The first two of these exist in the spectrum of Σ 6.

The prominent line in Nova's spectrum at λ 5751 has not yet been thoroughly searched for in other spectra. It does not appear to correspond to any of the prominent lines in the Wolf-Rayet stars. Last night I measured the wave-lengths of several bright lines in the spectrum of the star D. M. + 36° 3956. The prominent lines in the yellow are at λ 5812 ± 0.9 and λ 5688 ± 1.3. Thus the Nova line falls about midway between these.

Neither the magnitude nor the spectrum of Nova seems to have changed any since August 17, when it was first seen here. It is difficult to estimate the magnitude of Nova, on account of the distribution of the light in its spectrum. Its apparent magnitude is a function of the focusing and the color curve of the telescope. The very different estimates made by different observers can be explained largely by these facts. In the finder of the 36-inch telescope practically all the light of Nova is brought to a focus at one point, and it is clearly half a magnitude brighter than the star just north following it. In the great telescope, however, with the eyepiece adjusted to the stellar focus, the Nova and the star are very nearly of the same magnitude. When the eyepiece is in focus for the rays of wave-length 5007, the Nova is clearly brighter than the star.

In my former paper I should have stated that Professor Keeler's adopted wave-length of the chief nebular line, λ 5007.05, was taken from his unpublished manuscript, and is based upon Rowland's scale.

1892, Oct. 14.

THE ULTRA-VIOLET SPECTRUM OF THE SOLAR PROMINENCES.

III.

GEORGE E. HALE.

A photograph of the spectrum of a metallic prominence, taken at the Kenwood Observatory by my assistant, Mr. G. Duwalt, on Oct. 15, 1892, at $3^h 15^m$ (Plate D 1407) contains 74 bright lines in the ultra-violet between λ 3970 and λ 3630. The 12-inch photographic objective by Brashear and the spectrograph with 4-inch 14,438 grating and 3¼-inch glass objectives were employed.

The large number of lines obtained is rather surprising when the absorption of ultra-violet light in the three objectives is considered. All of the lines that I have previously photographed, as well as all those obtained by M. Deslandres with apparatus in which no glass is used, are shown on the photograph. In addition to these there are the following 32 lines, which were not previously known:

λ	λ	λ
3964	3863	3724.3
3956.9	3850.5	3716.9
3945.2	3813.5	3710.3
3938.1	3774	3699.5
3913.5	3767.1	3683
3965	3758	3681
3895.5	3757.0	3679.5
3893.8	3749.7	3674.2
3891	3741 7	3662.2
3878.8	3733.3	3647.8
		3632
		3630.8

New lines are also suspected at λ 3807.2, 3802, 3764, 3763, 3758.2, 3709.5, 3707.8, 3676, 3643.

The above wave-lengths are to be regarded as only approximate, as the conditions under which many of them were determined rendered great accuracy impossible.

KENWOOD OBSERVATORY, University of Chicago,
Oct. 25, 1892.

ASTRO-PHYSICAL NOTES.

All articles and correspondence relating to spectroscopy and other subjects properly included in ASTRO-PHYSICS, should be addressed to George E. Hale, Kenwood Observatory of the University of Chicago, Chicago, U. S. A. Authors of papers are requested to refer to page 848 for information in regard to illustrations, reprint copies, etc.

The Editorial Board of Astro-Physics.—Since the establishment of ASTRO-PHYSICS it has been the constant endeavor of its Editor to improve its contents in every possible way. A most important step has just been taken in this direction by the formation of a body of Associate Editors, consisting of Professor James E. Keeler, Director of the Allegheny Observatory, Dr. Henry Crew, Professor of Physics at Northwestern University, and Dr. Joseph S. Ames, of Johns Hopkins University. The important investigations by which these gentlemen have contributed to our knowledge of astronomical and terrestrial physics are so well known as to render unnecessary any word of introduction for the investigators themselves. It will be seen, however, that stellar and nebular spectroscopy will henceforth be fully represented in this journal through the services of Professor Keeler, while the more purely physical side of astro-physics will receive ample recognition through Professor Crew and Dr. Ames. We congratulate our readers and ourselves on the results which such coöperation must lead us to expect.

Asorption of Radiant Energy.—An interesting study of the absorption of radiant energy has recently been made by Mr. Bjerknes, and forms one of the contributions to the current number of *Wiedemann's Annalen*.

The writer confines his attention to the long wave-lengths and to metallic media. Using a primary conductor of Hertz's pattern, the radiations produced are examined in succession with a series of geometrically identical secondary circuits (resonators), each made of a different metal.

In this manner, each secondary receives the same amount of electro-magnetic energy and the same impressed electromotive force between the terminals of its spark micrometer.

But the *size* of the spark was found to vary between wide limits, thus showing that some metals dampen vibrations much more quickly than others. Of the six metals tried, copper gave the largest and iron the smallest spark. Copper is, therefore, the most transparent and iron the most opaque, substance on the list. In order of transparency, the list runs copper, brass, german silver, platinum, nickel, iron. This leads to the surprising result that *in these metals, at least*, the transparency is proportional to the electrical conductivity. Iron and nickel stand alone at the bottom of the list and appear to be more opaque than non-magnetic metals of the same conductivity.

In regard to this work, there may be some question as to just how much of the effect observed by Mr. Bjerknes may be due to the fact that these rapidly alternating currents travel only in the skin of the wire. At any rate, a comparison of the absorptive powers of these same metals, in thin films, for visible rays, and for that part of the ultra-red accessible to the bolometer, would be valuable. For here the displacement currents would be compelled to take place in the interior of the medium, albeit the medium might be very thin.

Method for Detecting and Exhibiting Hertzian Vibrations.—Among the many methods recently offered for the detection and exhibition of Hertzian vibrations one of the neatest is that proposed by Mr. Zehnder (*Wied. Ann. Bd. 47, pp. 77-92*). He employs the secondary spark to diminish the resistance between the electrodes of a Geissler tube, these electrodes being already connected to a source of electromotive force, nearly but not quite sufficient to produce a luminous discharge. The manner in which this is done is to seal the terminals of the resonator into the Geissler tube near the kathode.

The kathode and anode are then connected to the respective poles of a small induction coil which is synchronized with the Hertzian primary. Thus at the instant when the resonator spark passes there exists a pressure on the electrodes of the tube, and the sudden diminution of resistance due to the secondary spark makes this pressure sufficient to light the tube.

The method is evidently one requiring delicate adjustment and is useful only in the focal lines of reflectors: but it is a beautiful experiment for placing a large audience at once in possession of evidence for Maxwell's theory of light.

Line Spectrum of Hydrogen in the Oxyhydrogen Flame.—Professor Liveing of Cambridge has been making a very careful search for the line spectrum of hydrogen in the oxyhydrogen flame and has failed to find the slightest trace of any one of the hydrogen lines. Photographs and eye observations were each called into service.

Professor Liveing therefore concludes that Plücker was mistaken in his supposed observation of *C* and *F* in this flame. Those interested will find Professor Liveing's note in the October number of the *Philosophical Magazine*.

Solar Observations at Mt. Hamilton.—In the current number of *Nature*, Professor Henry Crew calls attention to the fact that the daytime seeing at the Lick Observatory is so influenced by local conditions as to make the 36-inch glass almost useless for visual work on the Sun.

On comparison of all three refractors belonging to this Observatory, the 6-inch and 12-inch were each found to give definition superior to that of the large instrument.

The cause of this is supposed to be the heated air which rises off the steep sides of the mountain and floats up over the Observatory at the top. The explanation will appeal to anyone who has spent a summer's day on Mt. Hamilton. In a comparison of this kind, the greater magnifying power of the larger lens is not to be forgotten.

On the Central Star of the Ring Nebula in Lyra.—The following note by Professor Keeler is reprinted from *A. N.* 3111:

Dr. Scheiner's interesting note in *A. N.* 3086, on the character of the central star in the Lyra nebula, leads me to mention some visual observations of my own which have a bearing on the same subject. The central star is beyond the reach of the Allegheny refractor, and all my observations were made in California, with the thirty-six inch telescope of the Lick Observatory. With this instrument the central star was always easily visible, although it was too faint for observation with the spectroscope.

Owing to the considerable chromatic aberration of so large a telescope, a gaseous nebula and its stellar nucleus cannot be seen distinctly at the same time; if the focus is adjusted on the star, the eye-piece must be drawn out a little to give a distinct view of the nebula. If the nebula presents any well-marked details, (like the beautiful planetary nebula G. C. 4373, in Draco), this peculiarity becomes very noticeable, and the difference of focus for the two objects may be easily measured. Professor Holden and Professor Schaeberle found the change of adjustment required in the case of the Draco nebula to be 0.44 inch. From a consideration of the color-curve of the objective, obtained by Vogel's spectroscopic method, the difference would appear to be somewhat less than this, perhaps from 0.35 to 0.40 inch, the exact value depending upon the position which the observer assigns to the focal plane for the three principal nebular lines, as the most satisfactory compromise. Thus the telescope itself roughly serves the purpose of a spectroscope, and in default of more accurate methods may give indications of value. Applying this method to the Ring Nebula in Lyra, I found that the same difference of focus was required, as nearly as I could judge, as for G. C. 4373, the central star being sharply seen when the eye piece was considerably inside the position required for the ring. Hence the maximum of light in the spectrum of the star is in the yellow or green, as it is in the nuclei of all the planetary nebulæ which are sufficiently bright for examination with the spectroscope.

Dr. Scheiner's conclusions in regard to the character of the central star therefore require some modification. It can hardly be doubted that the central star is actually formed from the nebula by a process of condensation; but it is not merely a brighter portion of the nebula, emitting radiations of the same character as the rest. Increased radiation in the lower part of the spectrum has accompanied the process of condensation. The nucleus so nearly approaches the stellar character that the general distribution of light in its spectrum is that of an ordinary star.

It may very well be, however, that the photographic energy of the star is due to bright lines in the violet part of its spectrum (most probably the hydrogen lines), the presence of which would add greatly to the photographic effect without displacing the maximum general brightness from the yellow. The nuclei of some planetary nebulæ which are within reach of the spectroscope are of this character.

It is possible to give another explanation, which accounts for the observed phenomena without attributing unusual properties to the central star. The photographic energy of a gaseous nebula resides very largely in the fourth line in its spectrum, or the $H\gamma$ line of hydrogen, and in different nebulæ various relations of brightness are found to exist between the hydrogen lines and the first and second nebular lines, while to these two last almost the whole visual effect is due. In the Orion nebula the hydrogen lines are relatively bright; in the intrinsically brilliant nebula N.G.C. 7027 they are relatively faint. Hence the brightness of a nebula is not a trustworthy indication of its photographic activity. Now the intrinsic brightness of the Ring Nebula is far below that of many smaller nebulæ, and moreover the hydrogen lines are relatively faint. Hence it may be that the prominence of the central star in the photographs may be due not to strength of photographic action of the star, but to weakness of that of the nebula, which is taken as the term of comparison. Obviously the true test would be to compare the central star, not with the nebulous ring, but with other stars on the plate, of the same visual magnitude, which are outside the limits of the nebula. It is possible that such comparisons have been made, although I do not know of any published results. In the only photographic representation of the Lyra nebula which I have, the plate in Pubblicazioni della Specola Vaticana, Fascicolo II, both the central star and the well known star following the ellipse are shown, The magnitudes of these stars have been variously estimated by different observers, and the former is sometimes regarded as variable. Mr. Burnham rates them as 15.4 and 12.4 respectively. In the plate mentioned, the larger star is about twice the diameter of the smaller. Whether two other stars of the same magnitudes would give similar discs I have no means of telling. The exposure of the photograph was one hour and fifty minutes.

It is quite possible that the photographic prominence of the central star is due to both causes, namely: partly to feeble action of the nebulous ring, and partly to strong action of the central star.

It should also be borne in mind that the relative prominence of these two features in the photograph is not determined solely by their natural difference of constitution, but in a large measure by the dimensions of the telescope employed. The brightness of the image of the nebula follows one law, that of the stellar image, another. JAMES E. KEELER.

Allegheny Observatory, Allegheny, Pa., 1892, July 5.

Schumann's Researches on the Extreme Ultra-Violet Part of the Spectrum.—Herr Victor Schumann has published in pamphlet form, as a reprint from the "Photographische Rundschau" for 1892, an account of his researches on the extreme ultra-violet spectra of the metals. The pamphlet gives a narrative of his experiments in this difficult field, rather than a final statement of the results obtained, and describes a number of improvements in his original apparatus which have enabled him to trace the ultra-violet spectrum farther than before, or above λ 1820. The experimental difficulties encountered in such work may be estimated from the fact that according to Cornu four inches of air are sufficient to completely absorb rays of wave-length 1566, and Schumann finds the absorption of air even greater than this. The optical train of fluor spar and the camera are therefore enclosed in a tight vessel which is exhausted by means of an air-pump, the sensitive plate being introduced through a kind of air-lock. According to Herr Schumann the spectrum of hydrogen has no fewer than five hundred lines in the extreme ultra-violet, their wave-lengths being, of course, subject to great uncertainty. An exhaustive account of his researches on the hydrogen spectrum will shortly be contributed by Herr Schumann to this journal.

Drawings of Mars.—The great number of drawings of Mars which have doubtless been made during the opposition just past will probably illustrate the personality of the observer in interpreting the faint markings presented to his eye, as well as serve their main purpose of recording the surface features of the planet. Certainly such drawings as have already been published show the effect of this personal interpretation very strongly. It is probable that fewer discrepancies would occur, particularly in the case of drawings made with telescopes differing greatly in size, if observers would pay more attention to the relative strength of markings. It is necessary to exaggerate the contrasts, but a uniform scale of intensity should be preserved throughout. A drawing made with a small telescope would then have a general resemblance to a distant view of one made with a large telescope.

The Cyclone Theory of Sun-spots.—The following note is from *Nature*, Sept. 22, 1892.

A somewhat prolonged absence from home has prevented me seeing until now your note on July 21, page 280, in which the writer remarks that the results of M. Camille Flammarion—published in the July number of *L'Astronomie* —"seem to confirm the view suggested by M. Faye that the constitution of [Sun] spots resembles somewhat that of the cyclones with which we are familiar.

I write to point out that this is not the theory of M. Faye, but, on the contrary, is the theory of Mr. Herbert Spencer, which he published in the *Reader* for February 25, 1865, and which has since been republished in his collected essays under the title, "The Constitution of the Sun." In it Mr. Spencer first points out the untenability of M. Faye's hypothesis, and then goes on to say:—"The explanation of the solar spots above suggested, which was originally propounded in opposition to that of M. Faye, was eventually adopted by him in place of his own. In the *Comptes Rendus* for 1867, vol. lxiv., p. 404, he refers to the article in the *Reader*, partly reproduced above, and speaks of me as having been replied to in a previous note. Again, in the *Comptes Rendus* for 1872, vol. lxxv., p. 1664, he recognizes the inadequacy of his hypothesis, saying:—'Il est certain que l'objection de M. Spencer, reproduit et développée par M. Kirchhoff, est fondée jusqu'â un certain point; l'intérieur des taches, si ce sont des lacunes dans la photosphère, doit être froid relativement . . . . Il est donc impossible qu'elles proviennent d'éruptions ascendantes.' He then proceeds to set forth the hypothesis that the spots are caused by the precipitation of vapour in the interiors of cyclones. But though, as above shown, he refers to the objection made in the foregoing essay to his original hypothesis, and recognizes its cogency, he does not say that the hypothesis which he thereupon substitutes is also to be found in the foregoing essay. Nor does he intimate this in the elaborate paper on the subject read before the French Association for the Advancement of Science, and published in the *Revue Scientifique* for March 24, 1883. The result is that the hypothesis is now currently ascribed to him. I should add that, while M. Faye ascribes solar spots to clouds formed within cyclones, we differ concerning the nature of the cloud. I have argued that it is formed by rarefaction, and consequent refrigeration, of the metallic gases constituting the stratum in which the cyclone exists. He argues that it is formed within the mass of cooled hydrogen drawn from the chromosphere into the vortex of the cyclone. Speaking of the cyclones, he says:—'Dans leur embouchure évasée ils entraîneront l'hydrogène froid de la chromosphère, produisant partout sur leur trajet vertical un abaissement notable de température et une obscurité relative, due à l'opacité de l'hydrogène froid englouti' (*Revue Scientifique*, March 24, 1883). Considering the intense cold required to reduce hydrogen to the 'critical point,' it is a strong supposition that the motion given to it by fluid friction on entering the vortex of the cyclone, can produce a rotation, rarefaction, and cooling, great enough to produce precipitation in a region so intensely heated."—(*Essays*, 1891 Edition, vol. i., pp. 188-9.)

Churchfield, Edgbaston. F. HOWARD COLLINS.

Solar Prominence Photography.—The following letter from Mr. Evershed is of such general interest that we insert it here.

KENLEY, SURREY, Sept. 11, 1892.

PROFESSOR GEORGE E. HALE, Chicago,

Dear Sir:—During the past summer I have been able to make a few further experiments in solar prominence photography, and believing you will be interested to hear of my success, I send you a short account of results so far obtained.

In the first place I have quite changed my opinion with regard to the supposed superiority of 'F' in this work, for to my great surprise I found H and K are not only very easy to photograph but are also easily seen reversed even with a wide slit.

The results, which appear to agree in every particular with your work, may be summarized as follows:

(1). H and K are strongly reversed in the chromosphere and in every hydrogen prominence.

(2). The forms of prominences in H and K are similar, but sometimes seem to be more extensive than in C.

(3). There is always a companion line to H on the lower side reversed in the chromosphere.

(4). On the disk immense regions near spots are brilliantly reversed in H and K, but the companion to H does not appear, nor do these reversals correspond at all with F reversals.

(5). These long reversals are frequently doubled over large areas, a fine absorption line appearing in the centre.

(6). In two negatives obtained the absorption shade in K (H is out of the field) is almost entirely wanting, whilst the centre is almost filled up with a brilliant double reversal.

(7). At the limb these reversals do not extend into (or above) the chromosphere except when overlaid by a hydrogen prominence.

I have not yet found any instance of a calcium prominence unaccompanied by hydrogen, or *vice versa*, and in this connection it is of interest to compare my drawing of May 21st with the photograph in the August number of

ASTRO-PHYSICS. Every prominence photographed is represented in my drawing in exactly the same relative position. I enclose copy of drawing. The only difference is in the very great depth of the chromosphere on the N. F. limb. Is this real or due to irradiation?

I enclose one or two film negatives to give an idea of the kind of results I get. The exposure ranges from one-fifth to one-half second and the image is magnified 4 or 8 times on the film.

I may mention also that I find the prismatic spectrum near H (5 prisms of 60°) is many times more brilliant than even the 1st order spectra of a small 14,438 line grating which the British Astronomical Association has lent to me. I therefore use the latter entirely for visual work and the prisms for photography. The negative with the date 3, 7, '92, was taken with a circular slit and shows the companion to H distinctly; also a bright metallic prominence in which the calcium lines are much widened; this was on the E limb just over a spot at 3:35 P. M. The paper print shows K with scarcely any absorption shade. It was taken at $2^h\ 5^m$ P. M. on June 5th, the slit being radial near a point on the S. P. limb where a brilliant eruption had occurred 4 hours earlier. Believe me, Yours truly,

J. EVERSHED, JR.

The photographs which accompanied the letter are excellent, and well illustrate Mr. Evershed's success with small instruments. The apparently greater depth of the chromosphere on the N. F. limb of the Sun in the photograph reproduced in the August number of ASTRO-PHYSICS is due to the fact that the diaphragm used in excluding the direct light from the Sun's surface was not exactly concentric with the image, and thus a portion of the photosphere was shown in the photograph.

Nova Aurigæ.—In *Nature* for September 22, 1892, Mr. H. F. Newall communicates his observations of the Nova on the night of September 14. The spectrum was observed with a compound prism between the eye and eye-piece, and was found to be faintly continuous, varying from C to F or G. There were also seen "a bright line quite, or nearly, coincident with C; three bright lines close together in the green, the least refrangible one seeming considerably broader than the others; a faint bright line in the blue (?F)," and a very faint line occasionally seen in the violet. No dark companion lines were seen. Observing with a power of 215 (without spectroscope) it was at first thought that the Nova was diffuse, and resembled a minute planetary nebula. It was eventually found, however, that the concentration of nearly all the Nova's light in the green caused it to have a focus different from that of other stars, and when compared with a neighboring equally bright star it was found when carefully focused to be distinctly the more point-like of the two.

In the *English Mechanic* for Oct. 7, 1892, Rev. T. E. Espin states that his estimate of the Nova's magnitude was hurriedly made, and should be given no weight. He further adds "I have found a close identity between the spectrum of Mira Ceti and the Nova Aurigæ. Comparing the photographs of Mira and the Nova, the lines are found generally to coincide, and, moreover, the duplication of the bands or lines in Mira is obvious. The conditions are, however, reversed in the Nova; the bright bands were on the less refrangible side; in Mira they are on the side of greater refrangibility. The mysterious line at 500 is probably present in the spectrum of Mira. Dr. Becker also calls attention to the correspondence of certain lines in the Nova and R Cygni, and R Andromedæ."

Telescopes for Amateurs.—The opposition of Mars and the discovery of a fifth satellite of Jupiter have caused a great accession of interest in astronomical matters among amateur observers. Mr. Brashear furnishes the following list of instruments which he has recently sold, or for which he has received orders, and says that in many cases the motive for ordering a telescope is stated to be that given above: 15-inch refractor, Mr. Sommers N. Smith, Newport News, Va.; 12-inch refractor, Beirut, Syria; 6-inch refractor, Lebanon, Ohio; 4½-inch refractor, Mr. F. G. Bennett, New Haven, Conn., 4½-inch refractor, Mr. J. H. Wilson, Brooklyn, N. Y.; 4½-inch refractor, Mr. D. H. Burrell, Little Falls, N. Y.; 4-inch refractor, Mr. Park Painter, Pittsburgh; 4-inch refractor, Mr. H. C. Frick, Pittsburgh; 4-inch refractor, Oil City High School; 3-inch refractor, State Normal School, Farmville, Va.; 3-inch refractor, Dr. A. C. Runion, Canonsburg, Pa.; 6-inch objective, Mr. N. Johnson, Manistee, Michigan; 6-inch photographic objective, Mr. Wm. Post, Bayport, N. Y.; 6-inch objective, Warner & Swasey, Cleveland, Ohio; 5-inch objective, Mr. Dayton C. Miller, Cleveland, Ohio; 4-inch objective, Mr. A. S. Grant, Palestine, Texas; 6½-inch reflector, Mr. J. A. Parkhurst, Marengo, Ill.; 6½-inch reflector, Mr. F. Dienelt, Loda, Ill.; 8½-inch speculum, Mr. H. Bradford, North Ferrisburg, Vt.

Besides the instruments above mentioned, which are mostly in the hands of amateurs, Mr. Brashear has since the beginning of the year, either furnished the following instruments to well-known observatories, or has them in course of construction:

12-inch objective with photographic lens, and 8¼-inch objective, for the new Dudley Observatory, Albany, N. Y.; 12-inch photographic objective, Kenwood Observatory, Chicago; 6-inch short focus photographic objective, Georgetown College Observatory; 6-inch photographic doublet, and 5-inch long-focus objective with amplifier, Goodsell Observatory, Northfield, Minn.; 5⅝-inch photographic objective and accessories for the Observatory of Meudon, France.

Photographing the Ultra-Violet Rays.—The following is the second report of the committee appointed to co-operate with Dr. C. Piazzi Smyth in his researches on the ultra-violet rays of the solar spectrum.

The present report is on the proposed experiments (from September, 1891, to January, 1892), for enabling Dr. C. Piazzi Smyth to improve certain points in the taking of his solar-spectrum photographs in the ultra-violet by aid of additions to the apparatus obtained through means of a grant from the British Association at Leeds in 1890.

The report continuates the last one by the same committee, as printed in the British Association's Cardiff volume of 1891, at pp. 147 and 148 thereof, said space being then taken up with little more than descriptions of what the apparatus, then only just finished, was intended for. Now, however, a sufficient amount of experiments have been obtained to allow the results to be classified and collated under three several heads, or thus:—

(1). Improved focussing means for setting the focus of the viewing, or photographic telescope, both more accurately and easily as well, from previous book-record, rather than from renewed eye-and-hand observation on every occasion. This was carried out mainly and successfully by supplying wheels ten inches in diameter, and nicely graduated on their circumferences to either end of the ordinary axle of pinion-movement of the focussing tube, taking care also to turn the said pinion at the last moment in the direction of increasing the readings and noting what they were. This record method of focussing, too, it is believed, is one which will be found of very general application, and much used every coming year, now that photography is continually substituting more and more the observer's eye and hand, with almost all kinds of optical notation of luminous phenomena.

(2). Improved magnifying means were next required for the viewing, and equally photographing, telescope. The chief feature necessary here was a large field with the increased magnifying power, and was given to a considerable extent by a grand Barlow-achromatic concave lens placed inside the usual telescope tube, by Messrs. T. Cooke & Sons, of York.

For mere magnifying, however, wherever the part of the spectrum under examination permits it without other addition, I have since then fully made up my mind that the second order of Professor Rowland's later and unprecedently fine Gratings from his new ruling engine, give sharper magnifying to the spectrum than any lens I have experimented with.

But they give it in a different way—*i. e.*, the second orders of Grating's spectra do; for they magnify only in one direction—that of separation—while a lens magnifies in a direction at right angles to that also. That feature is no doubt so much the worse for the lens, because it weakens the intensity of a continuous spectrum operated upon by it. But then there is another feature which is bad for the second, or any subsequently still more magnified spectrum-order of a Grating—viz., that they admit the red light of a previous order in the middle of their own violet; unless some possibly very absorptive liquid be employed to stop such red light where it is not wanted.

Now Messrs. Cooke's Barlow concave lens wants no help of that kind, for it was constructed to magnify the first order of spectrum only, and that has no red light of any other order intruding into its own ultra-violet, or requiring some chemical liquid to dull its potency. Hence I have actually found that I have been able to carry Messrs. Cooke's lenticular magnifying of the first order of a Grating's spectrum four plates further into the invisible than I was able to do with the second order of the very same Grating's spectra, assisted in various chromatic modes. As an illustration of which I beg to append a list of spectrum photographs so obtained last autumn.

(3). Lastly, my attention was kindly and earnestly directed by Professor Liveing to keep on the look-out for possible changes in some part or parts of the solar spectrum, depending on time and date only, especially if their origin should appear to be in the Sun.

Now it did so happen one morning that one of the glass negatives of the H and K region of the solar spectrum did show a very strange and anomalous difference from all the others, so different indeed that my first impression was to throw it away as irretrievably spoilt by some accident. But on considering what such an accident could be, or how it could be reproduced if desired, I was still more confounded and nonplussed. Having, moreover, Professor Liveing's letter still before me, the most respectful course seemed to be, on second thoughts, to describe publicly how the anomaly brought itself forward so far as I knew, and to leave gentlemen with more experience than myself to form their own opinions, either for or against its being anything important.

Now the main point of the anomaly is, that the whole space between H and K is bright, whilst that outside them is dark, even very dark. To understand which feature thoroughly and in the terms worked in by Nature, it was necessary that there should be several plates employed, and each of them should show, not only the whole space between those giant lines or bands, but at least as much more on either side.

Moreover, a good definition does not continue to hold all along even so smal a plate of glass as a quarter size, but has to be set and reset several times in its course, while the appearance of the lines alters almost radically on account of the mere curvature of the field. I enclose in an album case, in the first place, thirteen ordinary photographs of the H and K lines, taken at successive foci all across the field, and then three various impressions from one and the same anomalous photograph, No. 14; following that by Nos. 15 and 16, ordinary, but focussed to the right, views: the whole eighteen now exhibited being enlarged on paper to six times the size of the glasses, for convenience of examination. And I should, perhaps, duly forewarn all and sundry that "date" plays no part in the arrangement of this bundle of repetitions of the H and K lines—only the continual progress from left to right of the place of sharpest definition.

Occultation of Mars, Sept. 3, 1892.—The occultation of Mars on Sept. 3 was observed at Allegheny with the 13-inch refractor, which I had employed earlier in the evening in making drawings of the markings on the planet. Times were recorded on a chronograph by a Frodsham sidereal clock. At the first contact the limb of Mars was undulating considerably, and the observation was therefore somewhat uncertain. Reduced to Eastern Standard Time the observations are as follows:

First contact	13^h	21^m	$24^s.1$
Estimated bisection of disc	13	21	47 .9
Second contact	13	22	16 .8

At emersion the Moon was too low for observation. J. E. KEELER.

CURRENT CELESTIAL PHENOMENA.

PLANET NOTES FOR DECEMBER.

H. C. WILSON.

Mercury will be at inferior conjunction with the Sun Dec. 11 at $10^h\ 48^m$ A. M. The planet will then be nearly 2° north of the Sun's center. On the last day of December, Mercury will be at greatest elongation, about 23° west from the Sun, and will be visible to the naked eye in the morning.

Venus is still "morning star" and will be visible in the east in the morning during December.

Mars will be at quadrature, 90° east from the Sun, Dec. 9. He will be in good position for observation early each evening during the month. His apparent diameter decreases from 10″ Dec. 1 to 8″ Dec. 31.

Jupiter is at his best now, crossing the meridian at a high altitude a little after 10 P. M. During December he will be in excellent position for early evening observations. There are three very conspicuous belts this season and large telescopes show as many more. The great red spot still retains its outline of an ellipse with each end drawn out to a point. The central part is covered with a white cloud so that it is not quite as conspicuous as during last year. It is reported that Mr. Reed, Professor Young's assistant at Princeton, has been able to see the fifth satellite of Jupiter, with the 23-inch telescope. With this exception, so far as reported, it has not been seen with any other than the great Lick telescope.

Saturn may be seen in the morning. He is near the center of the constellation Virgo. The rings will now be quite plainly seen, as the elevation of the Earth above their plane is about 8°.

Uranus is too near the Sun yet to be well seen.

Neptune comes to opposition to the Sun on the morning of Dec. 1. It is therefore in position to be observed all night long. We hope next month to give a photograph of the region immediately about Neptune showing the faint stars.

Date. 1892.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Dec. 5	17 50.1	− 23 45	8 28 A. M.	12 50.0 P. M.	5 12 P. M.
15	16 56.9	− 20 08	6 42 "	11 21.6 A. M.	4 01 "
25	16 48.9	− 19 45	5 49 "	10 30.2 "	3 12 "
			VENUS.		
Dec. 5	14 28.4	− 12 36	4 16 A. M.	9 28.8 A. M.	2 42 P. M.
15	15 16.8	− 16 20	4 41 "	9 37.8 "	2 34 "
25	16 07.1	− 19 23	5 06 "	9 48.8 "	2 32 "
			MARS.		
Dec. 5	23 09.6	− 6 21	12 30 P. M.	6 08.5 P. M.	11 47 P. M.
15	23 32.5	− 3 36	12 03 "	5 52.1 "	11 41 "
25	23 55.8	− 0 48	11 36 A. M.	5 36.0 "	11 36 "
			JUPITER.		
Dec. 5	0 57.5	+ 4 36	1 35 P. M.	7 56.1 P. M.	2 18 A. M.
15	0 57.6	+ 4 40	12 55 "	7 16.9 "	1 39 "
25	0 59.0	+ 4 52	12 16 "	6 39.0 "	1 02 "
			SATURN.		
Dec. 5	12 43.6	− 2 13	1 50 A. M.	7 44.5 A. M.	1 39 P. M.
15	12 46.2	− 2 27	1 14 "	7 07.8 "	1 02 "
25	12 48.5	− 2 38	12 37 "	6 30.5 "	12 25 "
			URANUS.		
Dec. 5	14 25.5	− 13 58	4 19 A. M.	9 26.1 A. M.	2 33 P. M.
15	14 27.5	− 14 08	3 42 "	8 48.8 "	1 55 "
25	14 29.4	− 14 16	3 05 "	8 11.3 "	1 17 "
			NEPTUNE.		
Dec. 5	4 33.5	+ 20 21	4 02 P. M.	11 31.5 P. M.	7 01 A. M.
15	4 32.3	+ 20 18	3 22 "	10 51.1 "	6 20 "
25	4 31.2	+ 20 16	2 42 "	10 10.6 "	5 39 "
			THE SUN.		
Dec. 5	16 51.1	− 22 31	7 22 A. M.	11 51.1 A. M.	4 20 P. M.
15	17 35.2	− 23 20	7 30 "	11 55.7 "	4 22 "
25	18 19.6	− 23 23	7 36 "	12 00.7 P. M.	4 25 "

Occultations Visible at Washington.

Date 1892.	Star's Name.	Magnitude.	IMMERSION Washington M. T. h m	IMMERSION Angle f'm N pt. °	EMERSION Washington M. T. h m	EMERSION Angle f'm N pt. °	Duration. h m
Dec. 2	B.A.C. 1143	6	7 38	87	8 38	215	1 00
2	32 Tauri	6	14 42	28	15 25	306	0 43
5	47 Geminorum	6	11 34	129	12 34	231	1 00
7	B.A.C. 3138	6	11 28	98	12 38	290	1 10
8	η Leonis	3	12 02	87	12 54	334	0 52
28	29 Arietis	6	14 19	70	11 15	255	0 52
30	62 Tauri	6	10 43	11	11 20	315	0 37

Phases and Aspects of the Moon.

		d	h	m	
Perigee	Dec.	2	10	18	P. M.
Full Moon	"	3	8	17	"
Last Quarter	"	10	8	30	"
Apogee	"	15	7	18	A. M.
New Moon	"	19	2	13	"
First Quarter	"	26	3	22	P. M.
Perigee	"	31	6	06	A. M.

Phenomena of Jupiter's Satellites.

		h	m			
Dec.	1	9	26	P. M.	I	Oc. Dis.
	2	12	44	A. M.	I	Ec. Re.
		6	35	P. M.	I	Tr. In.
		7	44	"	I	Sh. In.
		8	49	"	I	Tr. Eg.
		9	54	"	II	Tr. In.
		9	57	"	I	Sh. Eg.
	3	12	10	A. M.	II	Sh. In.
		12	26	"	II	Tr. Eg.
		7	13	P. M.	I	Ec. Re.
	4	4	11	"	II	Oc. Dis
		4	25	"	I	Sh. Eg.
		8	55	"	II	Ec. Re.
		11	21	"	III	Tr. In.
	8	6	08	"	III	Ec. Dis.
		8	03	"	III	Ec. Re.
		11	16	"	I	Oc. Dis.
	9	8	26	"	I	Tr. In.
		9	39	"	I	Sh. In.
		10	40	"	I	Tr. Eg.
		11	52	"	I	Sh. Eg.
	10	12	22	A. M.	II	Tr. In.
		5	44	P. M.	I	Oc. Dis.
		9	08	"	I	Ec. Re.
	11	5	07	"	I	Tr. Eg.
		6	21	"	I	Sh. Eg.
		6	37	"	II	Oc. Dis.
		11	31	"	II	Ec. Re.
	13	6	37	"	II	Sh. Eg.
	15	4	48	"	III	Oc. Dis.
		7	13	"	III	Oc. Re.
		10	11	"	III	Ec. Dis.
Dec.	16	12	04	A. M.	III	Ec. Re.
		10	17	P. M.	I	Tr. In.
		11	34	"	I	Sh. In.
	17	12	31	A. M.	I	Tr. Eg.
		7	36	P. M.	I	Oc. Dis.
		11	04	"	I	Ec. Re.
	18	4	45	"	I	Tr. In.
		6	03	"	I	Sh. In.
		6	59	"	I	Tr. Eg.
		8	16	"	I	Sh. Eg.
		9	06	"	II	Oc. Dis.
	19	5	33	"	I	Ec. Re.
	20	6	43	"	II	Tr. Eg.
		6	46	"	II	Sh. In.
		9	14	"	II	Sh. Eg.
	22	8	38	"	III	Oc. Dis.
		11	05	"	III	Oc. Re.
	24	9	30	"	I	Oc. Dis.
	25	6	38	"	I	Tr. In.
		7	58	"	I	Sh. In.
		8	52	"	I	Tr. Eg.
		10	11	"	I	Sh. Eg.
		11	38	"	II	Oc. Dis.
	26	6	20	"	III	Sh. Eg.
		7	29	"	I	Ec. Re.
	27	4	40	"	I	Sh. Eg.
		6	43	"	II	Tr. In.
		9	17	"	II	Tr. Eg.
		9	25	"	II	Sh. In.
		11	53	"	II	Sh. Eg.
	29	6	02	"	II	Ec. Re.

Approximate Central Times when the Great Red Spot will pass the Center of Jupiter's Disk.

		h	m	
Dec.	1	4	40	P. M.
	2	2	36	A. M.
	2	10	28	P. M.
	3	6	19	"
	5	12	06	A. M.
	5	7	58	P. M.
	7	1	45	A. M.
	7	9	36	P. M.
	8	7	32	A. M.
	8	5	28	P. M.
	9	11	15	"
	10	7	06	"
Dec.	12	12	54	A. M.
	12	8	45	P. M.
	13	6	41	A. M.
	13	4	36	P. M.
	14	10	24	"
	15	6	15	"
	17	12	02	A. M.
	17	7	54	P. M.
	19	1	41	A. M.
	19	9	33	P. M.
	20	7	28	A. M.
	20	5	24	P. M.
Dec.	21	11	12	P. M.
	22	7	03	"
	24	12	50	A. M.
	24	8	42	P. M.
	25	6	38	A. M.
	25	4	33	P. M.
	26	10	21	"
	27	6	12	"
	28	12	00	midn.
	29	7	51	P. M.
	31	1	38	A. M.
	31	9	30	P. M.

Configuration of Jupiter's Satellites at 8h p. m. Central Time.

Dec.		Dec.		Dec.	
1	4 1 ○ 3 2	11	1 ○ 3 4 ●	21	4 3 2 ○ 1
2	♃ 4 ○ 2 3	12	3 ○ 1 2 4	22	4 1 ○ 2 ●
3	4 2 ○ 1 3	13	3 1 2 ○ 4	23	○ 4 1 2 3
4	4 1 ○ 2 3	14	3 2 ○ 4 1	24	2 1 ○ 4 3
5	3 4 ○ 1 2	15	4 ○ 1 2 3	25	♃ 2 ○ 3 4
6	3 1 2 4 ○	16	4 1 2 ○ 3	26	3 1 ○ 2 4
7	3 2 ○ 1 4	17	4 2 ○ 3 ●	27	♃ 3 1 ○ 4
8	1 ○ 3 2 4	18	4 1 2 ○ 3	28	3 2 ○ 1 4
9	○ 1 2 3 4	19	4 3 ○ 1 2	29	1 3 ○ 2 4
10	2 ○ 1 3 4	20	4 3 1 2 ○	30	○ 1 2 3 4
				31	2 1 ○ 4 3

Minima of Variable Stars of the Algol Type.

U CEPHEI.

R. A. .... $0^h\ 52^m\ 32^s$
Decl .... $+81°\ 17'$
Period .... $2d\ 11^h\ 50^m$

Dec. 2	3 A. M.
7	3 "
12	3 "
17	2 "
22	2 "
27	2 "

ALGOL.

R. A. .... $3^h\ 01^m\ 01^s$
Decl .... $+40°\ 32'$
Period .... $2d\ 20^h\ 49^m$

Dec. 8	4 A. M.
11	1 "
13	9 P. M.
16	6 "
19	3 "
28	5 A. M.
31	2 "

λ TAURI.

R. A. .... $3^h\ 54^m\ 35^s$
Decl .... $+12°\ 11'$
Period .... $3d\ 22^h\ 52^m$

Dec. 2	1 A. M.
5	midn.
9	11 P. M.
13	10 "
17	8 "
21	7 "
25	6 "
29	5 "

R CANIS MAJORIS.

R. A. .... $7^h\ 14^m\ 30^s$
Decl .... $-16°\ 11'$
Period .... $1d\ 03^h\ 16^m$

Dec. 4	8 P. M.

R. CANIS MAJ., CONT.

Dec. 5	11 P. M.
7	2 A. M.
8	5 "
12	6 P. M.
13	9 "
14	midn.
16	4 A. M.
20	5 P. M.
21	8 "
22	midn.
24	3 A. M.
29	7 P. M.
30	11 "

S CANCRI.

R. A. .... $8^h\ 37^m\ 39^s$
Decl .... $+19°\ 26'$
Period .... $9d\ 11^h\ 38^m$

Dec. 15	7 P. M.

S ANTLIÆ.

R. A. .... $9^h\ 27^m\ 30^s$
Decl .... $-28°\ 09'$
Period .... $0d\ 07^h\ 47^m$

Dec. 1	6 A. M.
2	6 "
3	5 "
4	4 "
5	4 "
6	3 "
7	2 "
8	2 "
9	1 "
10	1 "
10	midn.
11	11 P. M.

S. ANTLIÆ, CONT.

Dec. 12	11 P. M.
13	5 A. M.
14	5 "
15	4 A. M.
16	4 "
17	3 "
18	2 "
19	2 "
20	1 "
21	1 "
21	midn.
22	midn.
23	11 P. M.
24	6 A. M.
25	6 "
26	5 "
27	5 "
28	4 "
29	3 "
30	3 "
31	2 "

Y CYGNI.

R. A. .... $20^h\ 47^m\ 40^s$
Decl .... $+34°\ 15'$
Period .... $1d\ 11^h\ 56^m$

Dec. 1	10 P. M.
4	10 "
7	10 "
10	10 "
13	10 "
16	10 "
19	10 "
22	10 "
25	10 "
28	9 "
31	9 "

A Total Eclipse of the Moon, Nov. 4, 1892.—This will be invisible in the United States. The beginning is visible generally in the northwest part of North America, the Pacific Ocean, Asia, and the easterly portions of Europe. The end is visible in the northwest Pacific Ocean, Australia, Asia, Europe (except England and Spain) and the east portions of Africa. It begins at $7^h\ 10^m$ A. M. and ends at $12^h\ 20^m$ P. M. central standard time.

COMET NOTES.

New Comet Discovered by Photography, (*e* **1892, Barnard Oct. 12).**—A very faint comet was discovered photographically by Barnard, Oct. 12. Oct. 13.638 it was observed in R. A. $18^h\ 53^m\ 56^s$; Decl. $+12°\ 53'$. Daily motion $+6^m\ 44^s$; $-37'$. The following elements and ephemeris by Mr. Campbell were received by telegram Oct. 20.

Elements of Comet e 1892.

$$\begin{aligned} T &= \text{Aug. } 26.14,\ 1892 \text{ Gr. M. T.} \\ \omega &= 114°\ 02' \\ \Omega &= 184\ \ 13 \quad \Big\} \ 1892.0 \\ i &= 43\ \ 07 \\ q &= 1.9904 \end{aligned}$$

Ephemeris.

Gr. Midn.	R. A. h m s	Decl. ° ′	Light
Oct. 18	19 44 36	+10 42	0.85
22	19 53 32	9 17	
26	20 02 28	7 56	
30	20 11 24	+ 6 41	0.69

The comet was observed at Goodsell Observatory, Oct. 20 and found very near the ephemeris place. It is very faint, barely visible in the five-inch finder, but easily observed with the 16-inch. It is in the constellation Delphinus, the Dolphin, and moving southeast.

Five Comets Now Visible.—On the same night, Oct. 20, we looked up the other four comets which are now visible. Swift's is in the constellation Andromeda, between the head and right hand, moving slowly southward. It is yet visible in a five-inch and will continue to be within reach of large telescopes for some time yet. Winnecke's comet is in Cetus a few degrees southeast of the star β and is moving slowly northward. It is not visible in small telescopes and is rather difficult to observe with a 16-inch. Denning's comet is still fainter than Winnecke's. It will, during November, traverse the lower left corner of the constellation Orion. Brook's comet (*d* 1892) is the brightest of the five now visible. It is an easy object with a small telescope and will perhaps be visible to the naked eye. It is now in the fore paws of Leo, the Lion, and moving southeast.

New Elements of Comet *d* **1892 (Brooks.)**—The following elements and ephemeris were computed by Mr. A. G. Sivaslian, student at Goodsell Observatory, from observations at Northfield, Sept. 4 and Sept. 28, and one at Copenhagen Sept. 16.

$$\begin{aligned} T &= \text{Dec. } 28.04941,\ 1892, \text{ Gr. M. T.} \\ \omega &= 253°\ 04'\ 42''.0 \\ \Omega &= 264\ \ 27\ \ 49\ .9 \quad \Big\} \ 1892.0 \\ i &= 24\ \ 51\ \ 46\ .3 \\ \log q &= 9.986592 \qquad q = 0.96960 \end{aligned}$$

The representation of the middle place, $d\lambda \cos \beta = +1.8''$; $d\beta = -8.0''$, shows that the orbit is very nearly parabolic.

Ephemeris of Comet *d* 1892 (Brooks).

Gr. M. T.	App. R. A. h m s	App. Decl. ° ' "	log Δ	log *r*	Br.
Nov. 4.5	9 29 15.9	+ 8 57 15	0.0191	0.1230	12.9
5.5	33 21.4	8 09 25			
6.5	37 29.2	7 20 30			
7.5	41 39.5	6 30 32			
8.5	45 52.3	5 39 30	9.9998	0.1086	14.7
9.5	50 07.7	4 47 26			
10.5	54 25.5	3 54 22			
11.5	9 58 45.9	3 00 20			
12.5	10 03 08.9	2 05 20	9.9826	0.0943	17.0
13.5	07 34.5	1 09 26			
14.5	12 02.7	+ 0 12 41			
15.5	16 33.5	− 0 44 54			
16.5	21 06.9	1 43 14	9.9678	0.0801	19.5
17.5	25 43.0	2 42 16			
18.5	30 21.8	3 41 56			
19.5	35 03.2	4 42 11			
20.5	39 47.3	5 42 55	9.9560	0.0661	21.9
21.5	44 34.1	6 44 05			
22.5	49 23.6	7 45 35			
23.5	54 15.7	8 47 20			
24.5	10 59 10.5	9 49 16	9.9475	0.0526	24.3
25.5	11 04 07.9	10 51 17			
26.5	09 08.0	11 53 17			
27.5	14 10.8	12 55 11			
28.5	19 16.2	13 56 53	9.9427	0.0397	26.3
29.5	24 24.1	14 58 18			
30.5	29 34.5	15 59 20			
Dec. 1.5	34 47.5	16 59 53			
2.5	40 02.9	17 59 52	9.9416	0.0277	28.0
3.5	45 20.7	18 59 13			
4.5	50 40.9	19 57 48			
5.5	11 56 03.3	20 55 35			
6.5	12 01 27.8	21 52 28	9.9440	0.0167	29.1
7.5	06 54.4	22 48 22			
8.5	12 23.0	23 43 13			
9.5	17 53.6	24 36 58			
10.5	23 26.0	25 29 32	9.9496	0.0071	29.6
11.5	29 00.0	26 20 53			
12.5	34 35.6	27 10 56			
13.5	40 12.6	27 59 40			
14.5	12 45 51.0	− 28 47 02	9.9580	9.9991	29.6

Ephemeris of Comet *a* 1892 (Swift.)

[Computed by Geo. A. Law, student in Goodsell Observatory, from elements by Miss Gertrude Wentworth, *Astr. Jour.* No. 273].

Gr. M. T.	App. R. A. h m s	App. Decl. ° '	log. *r*	log. Δ	Br.
Nov. 5.5	23 44 09.8	+ 37 14.3	0.5060	0.3859	.027
6.5	44 6.7	36 57.7			
7.5	44 5.1	36 41.3			
8.5	44 4.9	36 25.1			
9.5	44 6.1	36 09.1	0.5121	0.3980	.025
10.5	44 8.7	35 53.2			
11.5	44 12.7	35 37.5			
12.5	44 18.6	35 22.0			
13.5	44 24.8	35 06.7	0.5180	0.4104	.023
14.5	44 32.8	34 51.6			
15.5	44 42.1	34 36.6			
16.5	44 52.7	34 22.0			

Gr. M. T.	App. R. A. h m s	App. Decl. ° ′	log. r	log. Δ	Br.
Nov. 17.5	23 45 4.6	+ 34 07.2	0.5238	0.4231	.021
18.5	45 17.7	33 52.8			
19.5	45 32.0	33 48.7			
20.5	45 47.5	33 34.8			
21.5	46 04.1	33 11.1	0.5295	0.4359	.019
22.5	46 21.9	32 57.6			
23.5	46 40.7	32 34.3			
24.5	47 00.6	32 21.3			
25.5	47 21.6	32 18.4	0.5351	0.4488	.018
26.5	47 43.7	32 05.8			
27.5	48 06.8	31 53.4			
28.5	48 30.9	31 41.2			
29.5	48 55.9	31 29.3	0.5406	0.4610	.016
30.5	49 21.9	31 17.6			
Dec. 1.5	49 48.8	31 06.1			
2.5	50 16.6	30 54.8			
3.5	50 45.4	30 43.8	0.5461	0.4747	.015
4.5	51 15.1	30 33.0			
5.5	51 45.5	30 22.4			
6.5	52 16.8	30 12.1			
7.5	52 48.8	30 01.8	0.5514	0.4877	.014
8.5	53 21.6	29 51.8			
9.5	53 55.2	29 42.2			
10.5	54 29.6	29 32.8			
11.5	55 04.5	29 23.5	0.5567	0.5005	.013
12.5	55 40.1	29 14.3			
13.5	56 16.4	29 05.4			
14.5	56 53.4	28 56.7			
15.5	23 57 31.0	+ 28 48.1	0.5619	0.5132	.012

Ephemeris of Comet 1892 (Winnecke).

(From *Astr. Nach.* No. 3112).

Berlin Midn.	App. R. A. h m s	App. Decl. ° ′ ″	log r	log Δ	Br.
1892 Nov. 16	0 49 17.7	− 19 19 17			
17	49 20.5	19 03 26	0.3101	0.1196	0.138
18	49 25.2	18 47 37			
19	49 31.5	18 31 51			
20	49 39.5	18 16 08			
21	49 49.2	18 00 28	0.3180	0.1426	0.120
22	50 00.4	17 44 51			
23	50 13.2	17 29 17			
24	50 27.6	17 13 46			
25	50 43.4	16 58 19	0.3258	0.1651	0.104
26	51 00.7	16 42 55			
27	51 19.4	16 27 34			
28	51 39.5	16 12 18			
29	52 01.0	15 57 05	0.3333	0.1870	0.091
30	52 23.7	15 41 56			
Dec. 1	52 47.7	15 26 52			
2	53 12.9	15 11 51			
3	53 39.3	14 56 54	0.3407	0.2083	0.080
4	54 06.9	14 42 01			
5	54 35.7	14 27 12			
6	55 05.5	14 12 28			
7	55 36.5	13 57 47	0.3479	0.2290	0.071
8	56 08.6	13 43 10			
9	56 41.6	13 28 38			
10	57 15.8	13 14 10			
11	57 50.9	12 59 45	0.3549	0.2492	0.062
12	0 58 27.0	− 12 45 25			

		App. R. A.			App. Decl.			log *r*	log *Δ*	Br.
		h	m	s	°	′	″			
Dec,	13	0	59	04.0	− 12	31	08			
	14	0	59	42.0	12	16	56			
	15	1	00	20.9	12	02	48	0.3618	0.2687	0.055
	16		01	00.7	11	48	43			
	17		01	41.4	11	34	43			
	18		02	22.9	11	20	47			
	19		03	05.3	11	06	54	0.3684	0.2876	0.049
	20		03	48.4	10	53	06			
	21		04	32.4	10	39	22			
	22		05	17.2	10	25	42			
	23		06	02.7	10	12	06	0.3750	0.3059	0.044
	24		06	48.9	9	58	33			
	25		07	35.9	9	45	05			
	26		08	23.5	9	31	41			
	27		09	11.9	9	18	22	0.3814	0.3236	0.039
	28		10	00.9	9	05	06			
	29		10	50.6	8	51	54			
	30		11	40.9	8	38	46			
	31	1	12	31.8	− 8	25	42	0.3876	0.3408	0.035

New Minor Planets.—Seven planetoids have been discovered since Sept. 1. All were discovered by means of photography, two being found on the same plate in two instances. The following are the dates and positions of discovery:

Planetoid.	Date.	R. A.		Decl.		Mag.	Photograph by	Place.
		h	m	°	′			
1892 B	Sept. 1	23	44.7	− 3	00	12	Staus	Heidelberg.
C	Sept. 1	23	55.4	− 4	11	11	Staus	"
D	Sept. 19	0	30.5	+11	32	12	Charlois	Nice.
E	Sept. 22-23	0	48.1	+ 8	35	11.5	Charlois	"
F	Sept. 25-26	0	41.7	+14	18	12	Charlois	"
G	Sept. 25	0	36.6	+ 0	21	12	Wolf	Heidelberg.
H	Sept. 25	0	37.6	+ 1	02	12	Wolf	"

The designation B, C, D, etc., is given temporarily. At the end of the year those which have not been identified with asteroids already known, and whose orbits are well determined will receive permanent numbers as heretofore. 1892 B is found to be identical with (163) Erigone. 1892 D was found on the same plate with (137) Melibœa and hence is not identical with it. G and H were found on the same plate with (34) Circe and (184) Dejopeja and are probably new.

The Partial Eclipse of the Sun, Oct. 20.—Clouds prevented observations of much value at Northfield. Both contacts were partially obscured. The first glimpse of the Moon's image notching the solar disk was caught by Miss C. R. Willard, observing with a 4-inch refractor by projection, at $10^h\ 41^m\ 36^s$ central standard time. Professor Payne observing with the same instrument, thought he saw the notch 20^s earlier, but it was immediately covered by a cloud so that he was uncertain. Professor Wilson using the 5-inch finder saw the notch at $10^h\ 42^m\ 20^s$ and estimated contact to have occurred about 5^s earlier. The clouds were so dense all the morning that we did not have time to adjust the helioscope on the 16-inch and so decided to use the finder.

Last contact was also very cloudy; the last glimpse of the black notch was seen by Professor Wilson, using the 16-inch telescope and helioscope, at $1^h\ 25^m\ 22^s$ central standard time. This was estimated to be about 5^s early. Three photographs of the eclipse were taken between clouds.

Observations of the Eclipse at Providence, R. I.—The partial solar eclipse was observed here at our Observatory yesterday under favorable conditions. The sky was nearly clear from first to last contact. The first contact occurred at $0^h\ 07^m\ 28.5^s$ eastern standard time, and the last contact at $3^h\ 08^m\ 08.0^s$. Professor Johnson observed with a three-inch telescope stationed in the open air, and I observed with a four-inch telescope. FRANK E. SEAGRAVE.

Providence, Oct. 21, 1892.

The Eclipse at Alta, Iowa.—The partial eclipse of the Sun was quite satisfactorily observed here on 20th inst. Heavy clouds covered the sky from early morning until about 10 A. M., when they suddenly broke away and only five minutes before the computed time of first contact the sky in the vicinity of the Sun was clear. First contact was noted at $10^h\ 23^m\ 10^s$ Alta mean time. Light haze now covered the sky for about an hour, but at time of ending of eclipse the sky was cloudless. Last contact occurred at $1^h\ 1^m\ 10^s$, Alta M. T. The observed times differ from my computed results by $1^m\ 20^s$ earlier and $1^m\ 16^s$ later for beginning and ending respectively, due I suppose to only approximate latitude and longitude of the station. Time was compared with fine regulator and noon signals at R. R. station. Telescope used, 3-inch Jena glass, full aperture employed.

DAVID E. HADDEN.

Alta, Ia., Lat. $+ 42° 40'$; Long. $95° 15'$ W. from Greenwich.

The Eclipse at Wilmington, N. C.—Mr. E. S. Martin writes that he observed the eclipse, under very favorable atmospheric conditions, with a 5-inch Clark refractor. He caught the first glimpse of the Moon at $12^h\ 08^m$, eastern standard time, a little after first contact. At $1^h\ 24^m$ the limb of the Moon occulted a conspicuous spot near the center of the Sun's disc. This spot reappeared at $2^h\ 30^m$ P. M. Last contact was not observed.

The Eclipse at Baltimore, Md.—I observed the partial eclipse as follows, using chronometer and chronograph:

	75 Meridian Time. h	m	s	Position Angle from north point. °
First Contact	12	05	12	21 west
Last Contact	3	05	45	105 east

J. STAHR.

NEWS AND NOTES.

New Director of the Paris Observatory.—M. F. Tisserand has been elected Director of the Observatory of Paris, in place of the late Admiral Mouchez. The election, in accordance with rules recently adopted by the Academy of Sciences and the Council of the Observatory, is for five years.

M. Tisserand is an eminent astronomer and mathematician, having published many memoirs in the scientific journals, which indicate his ability in scientific research. He is spoken of by the French papers as the real successor of Le Verrier. He is 47 years of age, has held several positions of responsibility and honor, and is well fitted to discharge the duties of the important office to which he has been called.

Note from Professor Keeler.—As my name has been mentioned in various articles commenting on recent changes in the Lick Observatory staff, I desire to say that I resigned more than a year ago for private reasons which were in no way connected with the administration of observatory affairs, and that I left Mount Hamilton with the good will of the regents and on the best of terms with the Director and all my associates. JAMES E. KEELER.

Allegheny Observatory, Sept. 24, 1892.

Letter from Professor Young.—I have the pleasure of reporting that my assistant, Mr. Reed, has succeeded in finding and observing the new satellite of Jupiter with the 23-inch equatorial of the Halsted Observatory. It had been looked for on every opportunity for the last three weeks, but unsuccessfully until Oct. 10th. During the earlier portion of the time, when the elongations occurred between 2 and 3 A. M., we were baffled by fogs which repeatedly gathered about that time;and later we were misled by bringing forward the time of elongation with the erroneous period of $11^h\ 50^m$. On Oct. 10th the *Western* Elongation should have been occurring, (reckoning on this basis) at the time, 12:40 A. M., Eastern Standard, when the satellite was actually found at the *Eastern* one.

The night of Oct. 10th was very fine, and Mr. Reed reports the satellite as *easily* seen,—certainly less difficult than Ariel. The elongation occurred at 12:40 as nearly as he could estimate, but the error of estimation might be as much as 10 minutes.

Two micrometer measures, which he obtained with much difficulty, at 1:09 and 1:49 A. M., gave the distance of the satellite from the planet's centre as 61".8 and 56".6 respectively.

On the 11th the satellite was seen again, and was judged to pass its elongation at 12:30 A. M. The air was not so clear as on the 10th, and no micrometer measures could be made.

I have not been able to participate in the observations myself, on account of an attack of rheumatism

A comparison of these two elongation-times with Mr. Barnard's early observations, given in the *Astronomical Journal*, and with another made on Sept. 23d and kindly communicated to me in a letter, gives the periodic time $11^h\ 57^m.0$, which I think must be correct within 10^s or so. In the computation the correc, tions for the planet's change of longitude and distance during the interval covered by the observations were duly applied, and the observed times of elongation are all satisfied without any error as great as four minutes. If as, I hope, we are able to get two or three more determinations of the time of elongation soon the probable error of the period can easily be brought down to a single second.

Assuming the mass of Jupiter as one, one thousand forty eighth of the Sun's, its mean distance as 483,300,000 miles, and its period 43,326 days, and taking the period of the satellite at $11^h\ 57^m.0$, we find its distance from the centre of the planet to be 112,500 miles, using the formula $r^3 = \dfrac{R^3t^2}{m.T^2}$

I may add that Mr. Reed considers the satellite bright enough to be seen (under favorable conditions of course) by any telescope exceeding 15 or 16 inches in diameter, but I should be disposed myself to doubt whether it could be reached by any object-glass much under 20 inches.

C. A. YOUNG.

Princeton, N. J., Oct. 13, 1892.

An Aerolite in Court.—A most interesting case, regarding the ownership of an aerolite, has just been decided by the Supreme Court of Iowa, in the case of Goddard *v.* Winchell. The facts are briefly as follows:

On the second day of May, 1890, an aerolite, weighing sixty-six pounds, fell on the land of one Mr. Goddard, imbedding itself in the soil to the depth of about three feet. One Mr. Hoagland, living on an adjoining farm, whose wife saw this aerolite fall, went upon the land the next day, with spade and pickaxe, dug up the aerolite, and took it to his own house, claiming it to be his own property, upon the ground that it could belong to no one else, except those who first found it and took it into their possession. A few days later Mr. Hoagland sold the stone to Mr. Winchell, whereupon the owner of the fee replevied the same, and hence arose the issue, as to the ownership of an aerolite. The question, plainly stated, was this: Does the stone belong to the man who owns the land upon which it fell, or does it belong to the first fortunate finder upon the ground that it formerly belonged to nobody, and hence would belong, when found, to the first person who should take it into his possession?

This is the first case of the kind which has ever been carried to a final decision, either in this or any other country. It is of interest to the scientific world in that it decides squarely of whom the scientist must purchase these messengers from abroad. Similar cases have been before the courts of limited jurisdiction, but never before has one been carried to the court of last resort. The questions placed before the Supreme Court of Iowa were as follows:

1. Does an aerolite belong to the owner of the fee, upon the ground "that whatever is affixed to the soil belongs to the soil?" or

2. Does it belong to the first finder, upon the ground "that the aerolite belongs to the great mass of unowned things and hence becomes the property of the first finder?"

If the first ancient rule of law is to be applied in this case, the stone must belong to the fee-holder. If the second principle is applied, then the finder will be the owner of the aerolite. The question of trespass in going onto the land of another to get property which fell there was not raised in this case, but the issue came up in the form above stated. The case was argued in the Supreme Court of Iowa by W. E. Bradford, of Britt, Iowa, and by Hon. W. S. Pattee of Minneapolis, the former appearing for the fee-holder, and the latter for Mr. Winchell, who purchased from the finder. The case was very thoroughly investigated, and elaborately argued upon both sides, and the Court finds the following, which stands as the syllabus of the reported case:

1. "An aerolite, weighing sixty-six pounds, which falls from the sky and is imbedded in the soil to the depth of three feet, is the property of the owner of the land on which it falls, rather than of the first person who finds it and digs it up."

2. "The rule that the finder of lost goods is entitled thereto, except as against the true owner, is not applicable to such case."

The main points of the Court's argument may be seen from the following extract from the Court's decision:

As conclusions of law, the district court found that the aerolite became a part of the soil on which it fell; that the plaintiff was the owner thereof; and that the act of Hoagland in removing it was wrongful. It is insisted by appellant that the conclusions of law are erroneous; that the enlightened demands of the time in which we live call for, if not a modification, a liberal construction, of the ancient rule, "that whatever is affixed to the soil belongs to the soil," or, the more modern statement of the rule, "that a permanent annexation to the soil, of a thing in itself personal, makes it a part of the realty." In behalf of appellant is invoked a rule alike ancient and of undoubted merit, "that of title by occupancy;" and we are cited to the language of Blackstone, as follows: "Occupancy is the taking possession of those things which before belonged to nobody;" and "whatever movables are found upon the surface of the earth, or in the sea, and are unclaimed by any owner, are supposed to be abandoned by the last proprietor, and as such are returned into the common stock and mass of things; and therefore they belong, as in a state of nature, to the first occupant or finder." In determining which of these rules is to govern in this case, it will be well for us to keep in mind the controlling facts giving rise to the different rules, and note, if at all, wherein the facts of this case should distinguish it. The rule sought to be avoided has alone reference to what becomes a part of the soil, and hence belongs to the owner thereof, because attached or added thereto. It has no reference whatever to an independent acquisition of title; that is, to an acquisition of property existing independent of other property. The rule invoked has reference only to property of this independent character, for it speaks of movables "found upon the surface of the earth or in the sea." The term "movables" must not be construed to mean that which can be moved, for, if so, it would include much known to be realty; but it means such things as are not naturally parts of earth or sea, but are on the one or in the other. Animals exist on the earth and in the sea, but they are not, in a proper sense, parts of either. If we look to the natural formation of the earth and sea, it is not difficult to understand what is meant by "movables," within the spirit of the rule cited. To take from the earth what nature has placed there in its formation, whether at the creation or through the natural processes of the acquisition and depletion of its particular parts, as we witness it in our daily observations, whether it be the soil proper or some natural deposit as of mineral or vegetable matter, is to take a part of the earth, and not movables.

If, from what we have said, we have in mind the facts giving rise to the rules cited, we may well look to the facts of this case to properly distinguish it. The subject of the dispute is an aerolite, of about 66 pounds weight, that "fell from the heavens" on the land of the plaintiff, and was found three feet below the surface. It came to its position in the earth through natural causes. It was one of nature's deposits, with nothing in its material composition to make it foreign or unnatural to the soil. It was not a movable thing "on the earth." It was in the earth, and in a very significant sense immovable; that is, it was only movable as parts of earth are made movable by the hand of man. Except for the peculiar manner in which it came, its relation to the soil would be beyond dispute. It was in its substance, as we understand, a stone. It was not of a character to be thought of as "unclaimed by any owner," and, because unclaimed, "supposed to be abandoned by the last proprietor," as should be the case under the rule invoked by appellant. In fact, it has none of the characteristics of the property contemplated by such a rule.

We may properly note some of the particular claims of appellant. His argument deals with the rules of the common law for acquiring real property, as by escheat, occupancy, prescription, forfeiture, and alienation, which it is claimed were all the methods known, barring inheritance. We need not question the correctness of the statement, assuming that it has reference to original acquisition, as distinct from acquisitions to soil already owned, by accretion or natural causes. The general rules of the law, by which the owners of riparian titles are made to lose or gain by the doctrine of accretions, are quite familiar. These rules are not, however, of exclusive application to such owners. Through the action of the elements, wind and water, the soil of one man is taken and deposited in the field of another; and thus all over the country, we may say, changes are constantly going on. By these natural causes the owners of the soil are giving and taking as the wisdom of the controlling forces shall determine. By these operations one may be affected with a substantial gain, and another by a similar loss. These gains are of accretion, and the deposit becomes the property of the owner of the soil on which it is made.

A scientist of note has said that from six to seven hundred of these stones fall to our earth annually. If they are, as indicated in argument, departures from other planets, and if among the planets of the solar system there is this interchange, bearing evidence of their material composition, upon what principle of reason or authority can we say that a deposit thus made shall not be of that class of property that it would be if originally of this planet and in the same situation? If these exchanges have been going on through the countless ages of our planetary system, who shall attempt to determine what part of the rocks and formations of especial value to the scientist, resting in and upon the earth, are of meteoric acquisition, and a part of that class of property designated in argument as "unowned things," to be the property of the fortunate finder instead of the owner of the soil, if the rule contended for is to obtain? It is not easy to understand why stones or balls of metallic iron, deposited as this was, should be governed by a different rule than obtains from the deposit of boulders, stones, and dirt upon our prairies by glacier action; and who would contend that these deposits from floating bodies of ice belong, not to the owner of the soil, but to the finder? Their origin or source may be less mysterious, but they, too, are "telltale messengers" from far-off lands, and have value for historic and scientific investigation.

It is said that the aerolite is without adaptation to the soil, and only valuable for scientific purposes. Nothing in the facts of the case will warrant us in saying that it was not as well adapted for use by the owner of the soil as any stone, or, as appellant is pleased to denominate it, "ball of metallic iron." That it may be of greater value for scientific or other purposes may be admitted, but that fact has little weight in determining who should be its owner. We cannot say that the owner of the soil is not as interested in, and would not as readily contribute to, the great cause of scientific advancement, as the finder, by chance or otherwise, of these silent messengers. This aerolite is of the value of $101, and this fact, if no other, would remove it from uses where other and much less valuable materials would answer an equally good purpose, and place it in the sphere of its greater usefulness.

The rule is cited, with cases for its support, that the finder of lost articles, even where they are found on the property, in the building, or with the personal effects of third persons, is the owner thereof against all the world except the true owner. The correctness of the rule may be conceded, but its application to the case at bar is very doubtful. The subject of this controversy was never lost or abandoned. Whence it came is not known, but, under the natural law of its government, it became a part of this earth, and, we think, should be treated as such. It is said by appellant that this case is unique; that no exact precedent can be found; and that the conclusion must be based largely upon new considerations. No similar question has, to our knowledge, been determined in a court of last resort. In the American and English Encylopedia of Law (volume 15, p. 388) is the following language: "An aerolite is the property of the owner of the fee upon which it falls. Hence a pedestrian on the highway, who is first to discover such a stone, is not the owner of it; the highway being a mere easement for travel." It cites the case of Maas v. Amana Soc., 16 Alb. Law J. 76, and 13 Ir. Law T. 381, each of which periodicals contains an editorial notice of such a case having been decided in Illinois, but no reported case is to be found. Anderson's Law Dictionary states the same rule of law, with the same references, under the subject of "accretions." In 20 Alb. Law J. 299, is a letter to the editor from a correspondent, calling attention to a case determined in France, where an aerolite found by a peasant was held not to be the property of the "proprietor of the field," but that of the finder. These references are entitled, of course, to slight, if any, consideration; the information as to them being too meager to indicate the trend of legal thought. Our conclusions are announced with some doubts as to their correctness, but they arise, not so much from the application of known rules of law to proper facts, as from the absence of defined rules for these particular cases. The interest manifested has induced us to give the case careful thought. Our conclusions seem to us nearest analogous to the general accepted rules of law bearing on kindred questions, and to subserve the ends of substantial justice. The question we have discussed is controlling in the case, and we need not consider others.

The judgment of the district court is affirmed.

The Photo-Electric Effect of Star-Light.—I forward to you an account of Professor Minchin's Photo-Electric Cells and the results obtained by Professor Dixon of St. John's, New Brunswick, who was residing next door to me during the time. The weather was on the whole very unfavorable. My telescope is a 7½-inch refractor by Alvan Clark (made for the late Rev. W. R. Dawes). It is an excellent instrument of its kind but accuracy of definition is unimportant for the purposes we had in view. In fact, I think we succeeded rather better when the cells were placed farther out than the focus so as to spread the light of the star over a wider circle. When the light is contracted almost to a point it is difficult to insure its falling on the sensitive plate. The cell, if used outside the tube, should, of course, be cut off from diffused light as far as possible. I am not sure that we attended sufficiently to this requirement. The fault, however, I think, chiefly rested with the electrometer (Clyton's form of Thomson's). Besides oscillating considerably, the zero-point appeared to be gradually shifting on some occasions, while on others the electrometer would not hold any considerable charge. I am not a practical electrician but I think those who are so will agree with me in this. We failed to obtain any *certain* results from the fixed stars owing, as I believe, to these causes. With a larger telescope and a steadier and less leaky electrometer, I think a good deal could be effected with Professor Minchin's cells. The effects obtained from the moon by Professor Dixon were of a striking character and on one occasion, at least, he obtained results from bright patches in the clouds near, but I think not precisely in front of, the moon. Professor Fitzgerald had previously obtained well marked effects from the moon. W. H. S. MONCK.

The Photo-Electric Effect of Star-Light.—Mr. Monck has asked me to give a short account of some preliminary experiments with Professor Minchin's photo-electric cells, in which he was good enough to ask me to assist. The experiments were made in Mr. Monck's Observatory in Earlsford Terrace, Dublin. The following arrangement was made at Professor Minchin's suggestion and by his assistance. The cell or battery of cells was placed on a small slide which was fitted to the tube of the telescope when the eye-piece was removed. This slide was so arranged that the sensitive part of plate in the cell could be placed in the focus of the telescope. By placing the eye behind the cell it was easy to see when the image of the star or planet fell on the sensitive plate, then the telescope was clamped and clock work set going. The sensitive plate was connected with a quadrant electrometer and the other plate with earth. The light from the planet could be cut off by a screen so that its effect on the cell could thus be determined by the deflection of the electrometer needle. The following results from a battery of two cells were obtained on the morning of the 28th of August: When an E M F of .85 volt gave a deflection of 21 cm. on the electrometer scale the effect of Jupiter's light on the battery produced a deflection of 4 mm.; and when the E M F of .85 volt gave a deflection of 10.5 cm. the light of Venus caused a deflection of 5 mm. STEPHEN M. DIXON.

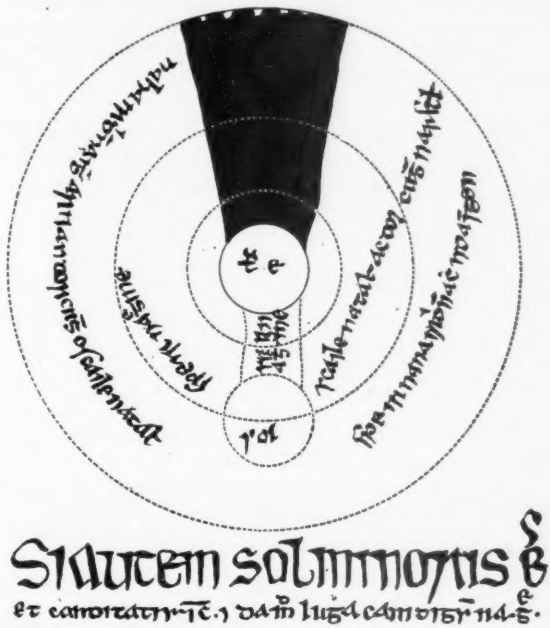
August 30, 1892.

A Curious Old Astronomical Chart.—We are indebted to Dr. William H. Grainger, East Boston, Mass., for a photographic copy taken from a facsimile of a curious astronomical chart, preserved in Trinity College, Dublin, bearing date A. D., 1400. The text is written in Celtic character and is somewhat faint, owing to the light brown color of the plate from which it was taken. The translation kindly furnished by Dr. Grainger is as follows:

"*Si Autem sol Minores eset Canditates*," *etc.*—If the magnitude of the Sun were smaller than the magnitude of the Earth, everything unsustainable, unpermissible, we have said, and move along with them, they should fall in it; for the shadow of the Earth would be continually growing and leaping from the Earth out to the sphere of the high stars, and it would darken the greater part of them;

and an eclipse would happen to the planets in every month; and the eclipse of the Moon would hold during the night, as he says. Well then, as we have never seen the like of this, and as we nave not heard, and as we have not found it written it must be that the magnitude of the Sun is not smaller than the magnitude of the Earth; and what I say is manifest from this figure down here.

(G.G) MS. in Roy. Ir. Acad. Astronom: Tract; Circa A. D. 1400.



Professor O'Curry says: "This remarkable astronomical tract does not appear to have been yet investigated by scientific scholars. A specimen has therefore been selected such as to show one of the many diagrams with which it is illustrated. It is a beautiful vellum manuscript of eight pages, in the finest style of handwriting."

Manuscript in R. I. A. (Circa 14th century).

The diagram contains the following words: (Translation).

1. The high stars on being darkened by the shadow of the Earth.
2. The Sun's sphere.
3. The Sun's sphere.
4. The shadow of the Earth darkening the Moon.
5. The sphere of the fixed stars.
6. The Sun.
7. The Earth.

Astronomical and Physical Society of Toronto.—The regular meeting of the Astronomical and Physical society of Toronto held Oct. 4, was one of lively interest to its members and visitors. Some of the topics considered were a permanent place for the books, apparatus and meetings of the society, arrangements for observing the Leonids, November 13 and 14; reports of auroræ for September, of large meteor by L. W. Smith; of Sun-spots; of occultation of Mars by the Moon, by Mr. Ridout; of the Barnard discovery of Jupiter's fifth satellite and of Jupiters opposition and the position of the shadows of satellites on the Jovian disc. Announcements of interesting phenomena for future observation were made and the promised work planned for somewhat in detail. This young society is doing useful work and engaging deserved public attention.

Chicago Academy of Sciences.—The regular meeting of the Section of Mathematics and Astronomy of the Chicago Academy of Sciences was held at the Dearborn Observatory, Evanston, on Tuesday evening, Oct. 4, 1892.

Professor G. W. Hough was in the chair.

The minutes of the last meeting were read and approved.

Mr. S. W. Burnham made some remarks on the new satellite of Jupiter. Mr. Barnard's discovery is by no means to be regarded as an accident, as Jupiter has been watched by this observer for many years. Up to June of the present year Mr. Barnard has been using the 12-inch telescope of the Lick Observatory in the examination of Jupiter's surface markings and the phenomena of the satellites. In July he was able for the first time to employ the 36-inch telescope for this work, and a very careful search was made for possible satellites. On Sept. 19 a very small star was seen close to the planet, and, as it was at once suspected to be a new satellite, its position with reference to the third Satellite was measured. On the two following nights it was re-observed and no doubt remained as to its true nature. It is described as a much more difficult object than the satellites of Mars, and therefore can probably be seen with only the largest instruments. The period is very nearly 11^h 59^m, and the distance from the planet's center about 112,000 miles.

Professor Hough spoke of the importance of the discovery, and of its relation to Galileo's discovery of the first four satellites.

Mr. Burnham added that the claims of the various observers with small telescopes as to their pretended discovery of the satellite were evidently not to be considered for a moment.

The next paper, "On the New Star in Auriga," was read by Dr. Henry Crew of Northwestern University. The discovery and earlier observations of the Nova were described, and the various remarkable features of the Nova and its spectrum were pointed out. Professor Crew's observations were made with the 36-inch telescope of the Lick Observatory. With a single prism the spectrum was very brilliant, but it was very faint with a grating. Attention was called to the peculiar way in which the lines faded away as the star declined in magnitude. Two lines in the red which were very faint when the Nova was brightest became brighter as the magnitude decreased, and finally surpassed even C itself. Dr. Crew considers the reappearance of the Nova as a nebula as distinctly opposed to Mr. Lockyer's meteoritic theory. The various other theories were reviewed and commented upon.

Mr. Burnham remarked, in answer to a question as to the position of the Nova, that Mr. Barnard had found by a series of measures that not the slightest change had occurred since the disappearance in the spring. He considers the mode of discovery as offering great encouragement to amateurs having small instruments. An observer with a large telescope depends so exclusively upon the circles in setting that he loses his familiarity with the sky. The amateur observer's constant use of star charts makes it much more likely that he will notice new objects, though many probably escape attention.

Dr. Crew exhibited Professor Campbell's new map of the Nova's spectrum, and pointed out the chief nebular line.

In speaking of Mr. Barnard's observations of an extremely faint nebulosity now surrounding the Nova, Mr. Burnham expressed his perfect confidence in Mr. Barnard's ability as an observer by stating that he would rather trust Mr. Barnard's observations of a very difficult object than believe in the testimony of his own eye.

Professor George E. Hale, of the Kenwood Observatory described an automatic spectroheliograph recently devised by him. When once adjusted and set in operation the instrument will take photographs of the Sun showing spots, faculæ and prominences, at any desired interval throughout the day. It is expected that such an instrument will soon be in daily use at the Kenwood Observatory.

Professor Hale also presented some remarks on a recent communication by M. Deslandres to the Paris Academy of Sciences. In his paper M. Deslandres suggests a method for determining the velocity of the axial rotation of stars. The method depends upon M. Deslandres' statement that the solar faculæ are sometimes sufficiently bright to show the H and K lines reversed in the solar spectrum as photographed with an integrating spectroscope. Professor Hale criticised M. Deslandres' method, and proposed a means of testing its applicability which will shortly be presented to the Paris Academy of Sciences.

Dr. Crew remarked that he considered M. Deslandres' method disposed of by Professor Hale's criticism, and thought it hardly necessary that the test be applied.

Professor Hough made a few remarks on the present appearance of Jupiter and the Red Spot, which is now very faint, and may completely disappear. He considers it identical with the spot seen by Cassini to appear and reappear every six years.

The meeting then adjourned, and the remainder of the evening was spent by the members in observing Jupiter and other objects with the 18½-inch equatorial of Dearborn Observatory. GEORGE E. HALE, Recorder.

BOOK NOTICES.

Cosmical Evolution. A New Theory of the Mechanism of Nature. By Evan McLennon. Messrs. Donohue, Henneberry & Co., Publishers, Chicago. 1890. pp. 399.

This book offers a new system of cosmical evolution which embraces the entire range of natural phenomena, although only the elementary conceptions of it are yet published. The introduction contains a statement of various legends of creation and primitive ideas and the successive theories of astronomical science from the Ptolemaic system to the Nebular Hypothesis. The body of the work is divided into three parts: An introduction to the theory, objections to the theory and finally the new theory itself. In the first part, we find the essential principle of the new theory, the sole characteristic of it, stated in these words:—"*Every known heavenly body is connected with its neighboring heavenly bod-*

ies by means of real, material bonds, and that every phenomenon of the universe, without exception, is due solely to the action of bodies upon one another through, and by means of, these bonds that join them together." It is the purpose of the book to prove this proposition, or, at least, to make it more probable than existing theories incompatible with it. The idea of force as commonly used by physicists is abandoned, and all argument is made to turn on the "all-sufficiency of matter and motion," in one grand chain of causation. The gist of the theory, stripped of all verbage, is simply this: What are these "real, material bonds" that constitute the solid "connections" of the different parts of the universe? Physicists say the union is sustained by force, but no scholar attempts to give a complete definition of force, because no one knows what it is. Now, it seems to us that the new theory does not help us any in the place of real difficulty, for what are these "real, material bonds?" What has been added to our knowledge of cause or effect by this discussion? We are free to say that the author has, in the main, stated well real objections to existing theories, but, on the other hand, we fail to see how he has given aid at the point where it is needed. We have been interested in the range of fact presented, and often the good popular statement given to difficult and unsettled questions of science. The book is an honest attempt to do real service in studying hard and knotty problems in physical science.

Questions and Answers about Electricity. A First Book for Beginners. Edited by E. T. Bubier 2d. By D. Van Nostrand Co., New York, 1892. pp. 100. Price 50 cents.

This is a very suggestive little book in the form of questions and answers with illustrations of electrical instruments where needed to give more definite ideas of principles or methods in the science. The Van Nostrand Company is doing science excellent service in publishing so many good books in cheap monograph form.

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